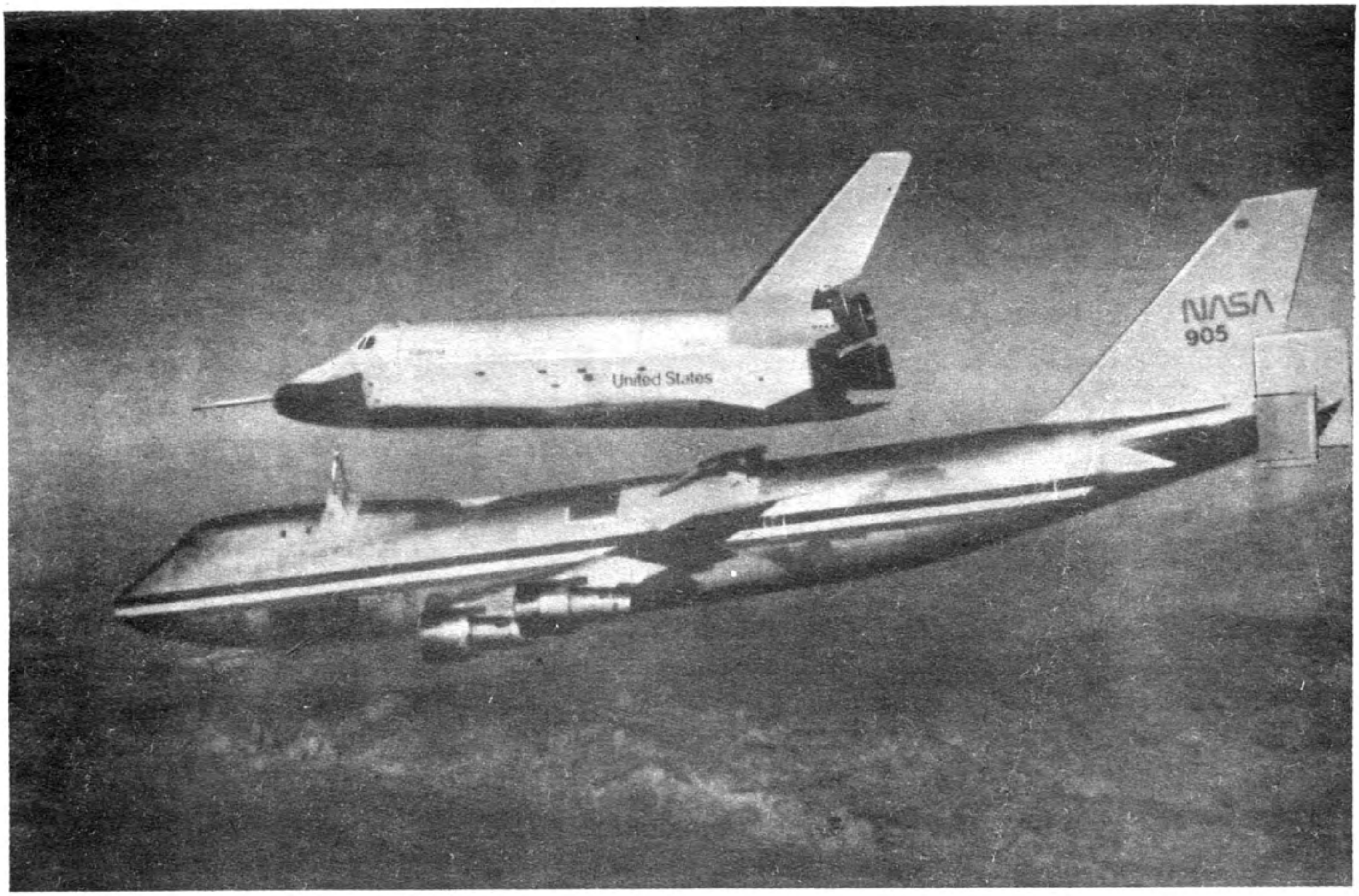
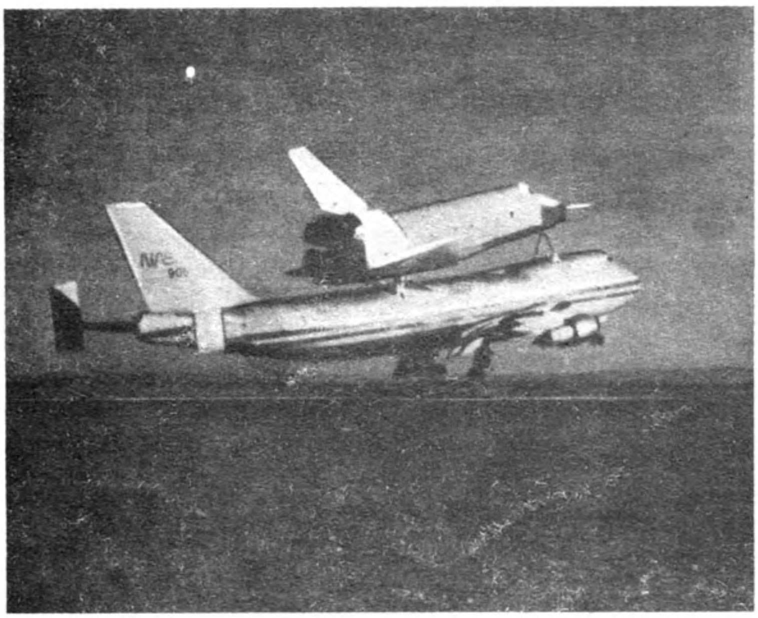
SPACEFLIGHT





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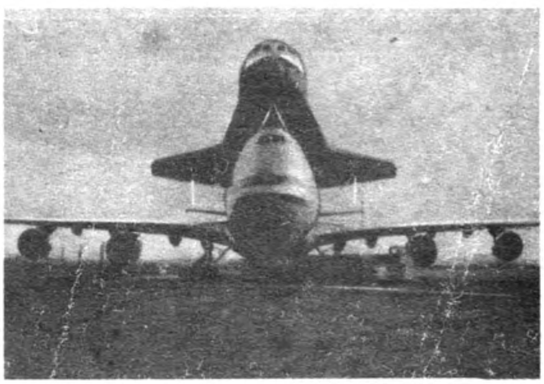

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 20 NO. 1 JANUARY 1978 *Published 25 December 1977*

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CONTENTS

COVER

GLIDE TESTS END. Astronauts Fred W. Haise and C. Gordon Fullerton on 26 October 1977 brought to a successful conclusion the series of glide tests of the Shuttle 'Enterprise' from the Boeing 747 'mother' at Dryden Flight Research Center in California. Our photographs illustrate to previous glide test of 12 October flown by Joe H. Engle and Richard H. Truly. Test work now resumes at the Marshall Space Flight Center at Huntsville, Alabama, to which the spaceplane will be flown on its 747 carrier on 17 March. The craft will remain at MSFC for 10 months for vibration testing mounted in the same dynamic test stand used for the Saturn 5 Moon rocket in the 1960's. Three configurations will be tested: Orbiter and empty External Tank (main engine burnout); Orbiter, partially-full tank and empty Solid Rocket Boosters (booster burnout), and Orbiter, full tank and boosters (lift-off).

National Aeronautics and Space Administration

Cover design by David Holmes

MILESTONES

October

10 British Aircraft Corporation, Electronic and Space Systems, at Bristol, announces receipt of ESA contracts totalling £13.3 million "to develop and manufacture the Solar Array and a Photon Detector Assembly" for NASA's Space Telescope being built by Lockheed Missiles and Space Company.

12 Space Shuttle 'Enterprise,' with astronauts Joe H. Engle and Richard H. Truly, makes fourth free flight from Boeing 747 'mother,' but first in which the streamlined tail fairing was removed and three dummy rocket engines were exposed in the 'high-drag' configuration. 'Enterprise' touched down some 5,000 ft. (1,524 m) down the dry lake runway after a flight lasting just 2 min. 34 sec. Orbiter's handling characteristics were not significantly different from those with the tail fairing on. Aerodynamic buffeting on the 747 was less of a problem than anticipated. Main effect of the reduced lift/drag performance was a greater glide slope angle of more than 25 deg at one stage during the final approach.

22 NASA launches mother-daughter ISEE-A and ISEE-B (International Sun-Earth Explorer) satellites by Delta 2914 from Cape Canaveral at 13.53 hr. GMT (see page 16). ESA reported: "After travelling on the launcher's normal trajectory the two satellites separated, as planned, one hour after launch. All the operations scheduled for the first 24 hours in orbit were carried out as planned, in particular the slowing down of ISEE-B and the deployment of its hinged booms. After a series of checks carried out over the first four orbits, ISEE-B was orientated in a new attitude with its spin axis perpendicular to the plane of the ecliptic." Orbit ranges between 280 and 138,317 km inclined at 28.6 deg to equator.

25 Soviets launch geophysical rocket Vertikal 6 from Kapustin Yar to altitude of 1,500 km (932 miles). Experiment, carried out under programme of cooperation with socialist countries, is designed to continue "complex exploration of the Earth's atmosphere and ionosphere as well as the interaction of the Sun's short wave radiation with the Earth's atmosphere." The stabilised recoverable instrument capsule carried research equipment made in Bulgaria, Czechoslovakia, Hungary and the USSR. After separating from the rocket at a height of 173 km, the capsule soared to its zenith and subsequently ejected a parachute for recovery. At the same time small meteorological rockets were launched to obtain synoptic observations at 100 km and also close to the ground.

26 Space Shuttle 'Enterprise' with astronauts Fred W. Haise and C. Gordon Fullerton, makes fifth and last free flight from Boeing 747 'mother' at Dryden Flight Research Center, Edwards, California. Separation occurred at 17,000 ft. (5,181 metres) altitude directly in line with Runway 22, the glide lasting 1 min. 59 sec. Lift/drag ratio was higher than expected. Craft landed heavily on one set of undercarriage wheels causing it to bounce and tip three times to the right. Bounce was caused by 'hot' landing which made Haise lower the elevons to get the nose down, making the Orbiter crab into the air at a slight angle.

26 Soviets launch Cosmos 961 in anti-satellite test passing close to Cosmos 959 target placed in orbit on 21 October. Target was orbiting between 158 and 820 km at 66 deg to equator. According to a *Tass* announcement, Cosmos 961 was placed into a 125 x 302 km orbit at similar inclination but NORAD tracking indicates that interceptor was manoeuvred upwards from initial parking orbit to achieve trajectory of 269 x 1,421 km

[Continued on page 8

(2)

INTO SPACE BY LOW TECHNOLOGY?

By Kenneth W. Gatland

Introduction

Attempts to build rockets cheaply using the simplest possible methods of construction have a long history. Several of the early pioneers of Astronautics, including Hermann Oberth, strove for this ideal, and as late at the 1960's strenuous efforts were made in the United States (by Truax at Aerojet, etc.) to make it a reality in the shape of "the big dumb booster".

It is a matter of public record that none of these efforts met with great success.

Today the same ideal is being pursued by a West German company – the Orbital Transport and Raketen AG (OTRAG) – which has acquired rights in Zaire, Central Africa, to set up an extensive rocket range for launching "low-technology" rockets of novel design.

The company is raising money from private investment and bank loans to begin large-scale production.

Modular Construction

The rockets are being put together using clusters of standardised engines. The technique, in fact, is oddly reminiscent of the staging arrangement adopted in the classic BIS moonship study of 1937-39. However, instead of using batteries of solid rockets, the Germans are clustering modules of nitric acid/kerosene rockets circumferentially upon the first stage in a parallel arrangement. In this way, it is claimed, different launch vehicles for a wide range of missions can be assembled using the same basic "building blocks".

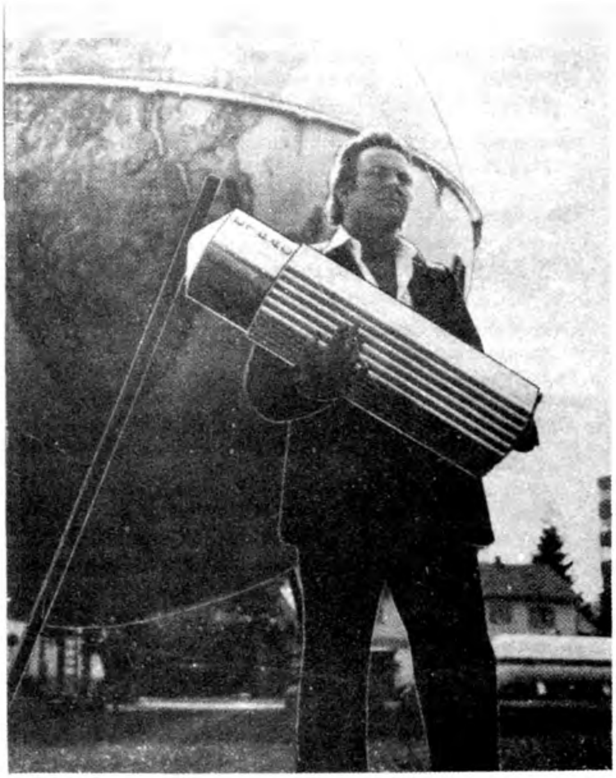
OTRAG insist that costs will be greatly reduced by this method of standardisation and that reliability will be increased. They say that rockets can be assembled to meet thrust requirements of 2 to 2,000 tons – from high-altitude research rockets to large launch vehicles for commercially useful satellites.

The idea is the brainchild of Dipl-Ing Lutz T. Kayser, President of OTRAG, who has the support of the veteran rocket pioneer Dr. Kurt H. Debus who launched V-2s at Peenemünde, subsequently went to Huntsville with von Braun, and was later responsible at Cape Canaveral for launching all the Saturn rockets of the Apollo Moon programme. Since his retirement from NASA in 1975, Debus has been chairman of the Board of OTRAG.

The Standardised Propulsion Module

Kayser's basic philosophy is to standardise propulsion units in the form of cylindrical modules (tanks and engines) which can be assembled into rockets of different size.

Each propulsion module has a combustion chamber and nozzle, with injector, valves, electrical valve actuator with electronic logic and its own battery power supply. OTRAG says it represents "the first fully autonomous rocket engine that just needs control commands".



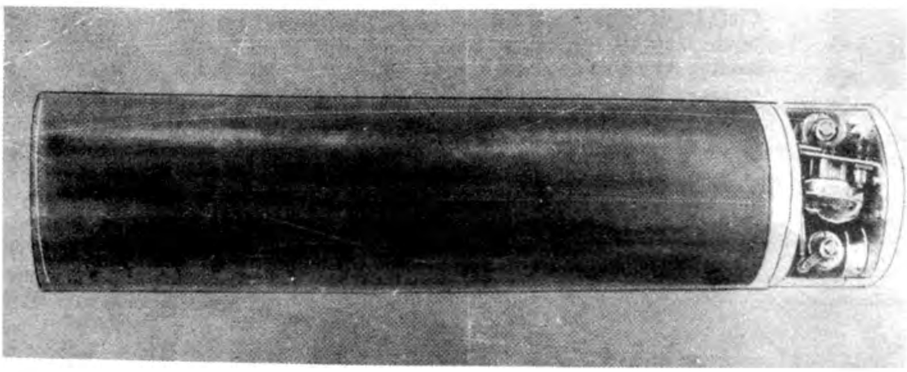
Lutz T. Kayser, President of OTRAG, holds a model of the 1,000 ton modular rocket he hopes to launch from Zaire in 1981.

All photos OTRAG Orbital Transport und Raketen AG, copyright Dipl.-Ing K. Wukasch

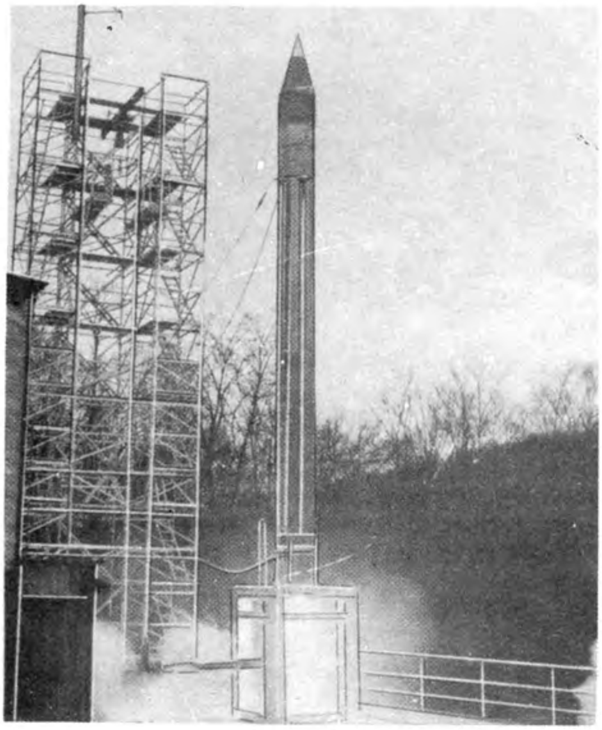
Clustering this engine module is basically simple because it has only to be connected to the propellant supply lines after which it is immediately operational. The simplicity of construction, and the use of only commercially available components and materials, are claimed to have reduced production costs to one-thirtieth of contemporary rocket systems.

Another key feature is the method of control which is not achieved by technically complicated gimballing of thrust chambers but by the throttling of individual modules of the engine cluster.

The technique has been tested to the satisfaction of OTRAG engineers and intensive computer simulations are



Standard rocket engine of three tons thrust for use in single or clustered arrangements. It burns concentrated nitric acid and kerosene and can be throttled to 50 per cent of rated maximum thrust.



OTRAG rocket on static test. The four clustered standard engines produce a total thrust of 12 tons.

stated to have proved excellent control behaviour.

Another advantage of this arrangement is that very compact clustering is possible which does not leave space between individual engines. This avoids the danger of the backflow of hot gases between the engines during first stage operation. Throttling (up to 50 per cent) is performed by clustering the main engine valves without the intervention of any additional components, a feature which "has never been demonstrated before".

Adiabatic Propellant Feed

One of the most complicated problems in launch vehicles has been solved by using an "adiabatic feed system". The tanks of fuel and oxidiser are only 60 per cent filled, the ullage volume being filled with compressed nitrogen up to the desired starting pressure, e.g. 30 bar.

Immediately the engine valves open the nitrogen forces the propellants into the thrust chambers, which have radial injection and ablative cooling.

The company claims that much is to be gained, in reduced costs and improved reliability, by eliminating turbopumps even in large rockets. "It depends on the physical principle of the adiabatic expansion of a gas that never can fail because all mechanical and electrical components are eliminated".

Although the propellant feed pressure in the tanks decreases with time, the standard rocket engine "is the only known motor that can operate in a feed pressure range between 30 and 10 bar without instability".

More than 1,000 tests have now been made during the development and qualification period, culminating early last year in the test firing of a cluster of six standard rocket modules in a government DFVLR test stand at Lampoldshausen, near Stuttgart; a total thrust of some 20 tons was achieved.

From the beginning rocket parts have been manufactured in the workshop with due regard for future mass production. For example, it has been possible to make the tanks of nickel-based alloys adopting the production techniques employed in the fabrication of spiral welded pipes. It is claimed that this reduces the specific cost per pound of launch vehicle structure to one-twentieth of the contemporary value.

Propellants

Cost, density and performance are the most important properties in the selection of a propellant. OTRAG concludes that concentrated nitric acid and kerosene best meet these requirements and is currently available at a cost of approximately 600 DM/ton (£150/ton). Had the rocket been designed to use UDMH and nitrogen tetroxide, propellant costs would have been 20 times as great!

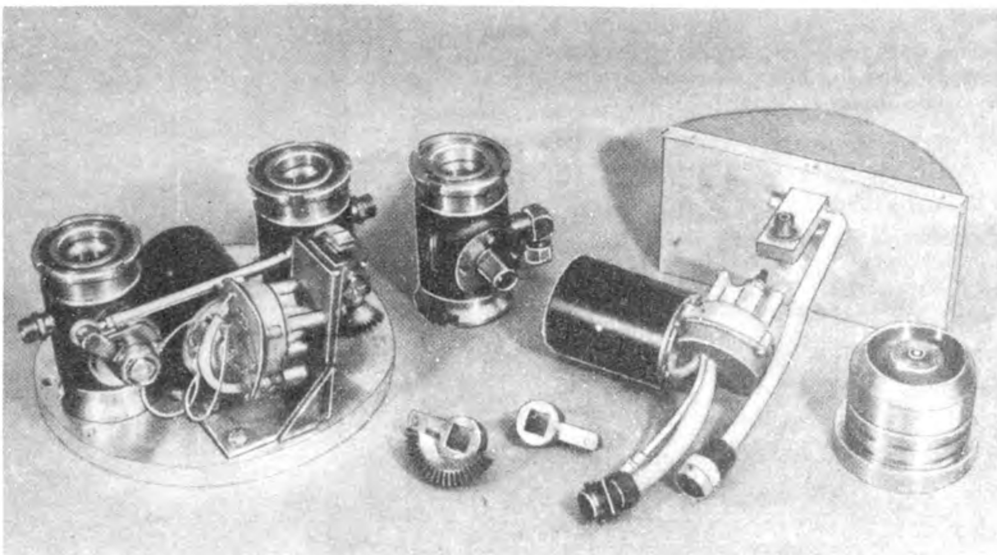
OTRAG claims that up to 10 standard propellant tanks per day can be produced on a single machine which is fully automated.

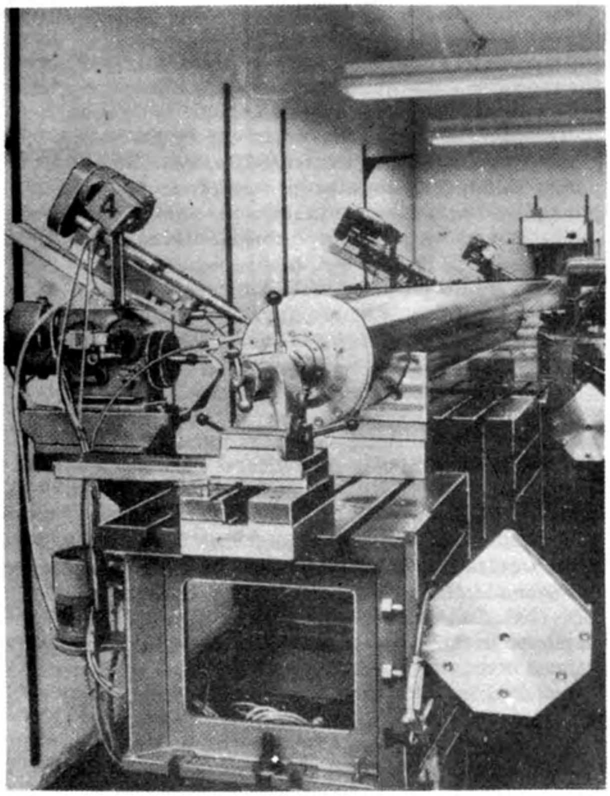
The first batches of clustered tanks were assembled at the DFVLR test facility.

Payload

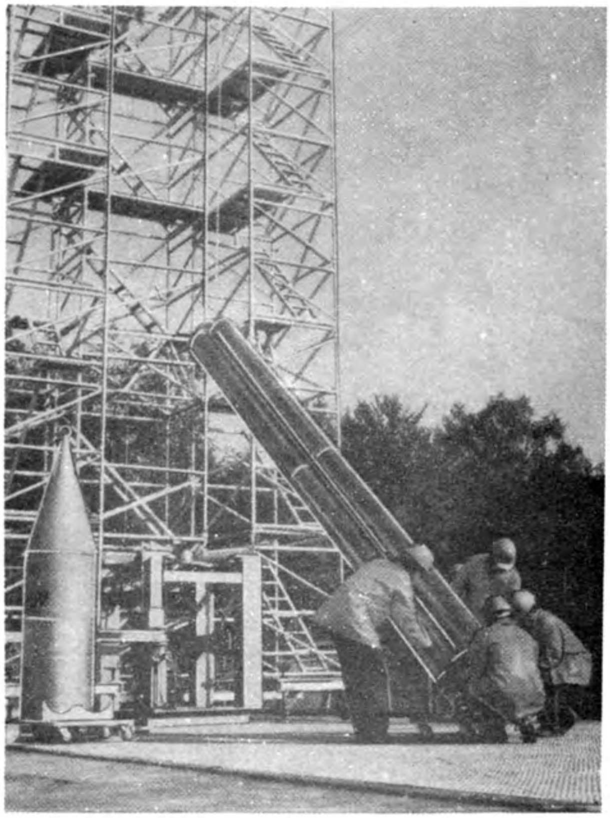
Depending on the desired mission, the cylindrical pay-

The standard rocket engine combining an engine and propellant tank is claimed to be "the first completely autonomous engine with integrated combustion chamber, injector, valves, valve actuator, electronic logic and electrical power supply." Some major components are seen in this picture.





Machine for the fully automated manufacture of propellant tanks. Up to 10 tanks per day can be produced on a single machine.



Erection of the clustered propellant tanks at the DFVLR test facility at Lampoldshausen near Heilbronn, West Germany.

load section can accommodate physical measuring or other equipment, guidance and control instruments, telemetry transmitter and a parachute recovery system. This payload unit can easily be exchanged or replaced.

Fuelling

Shortly before take-off the vehicle is fuelled by a fully automatic system with white fuming nitric acid and kerosene.

Checkout

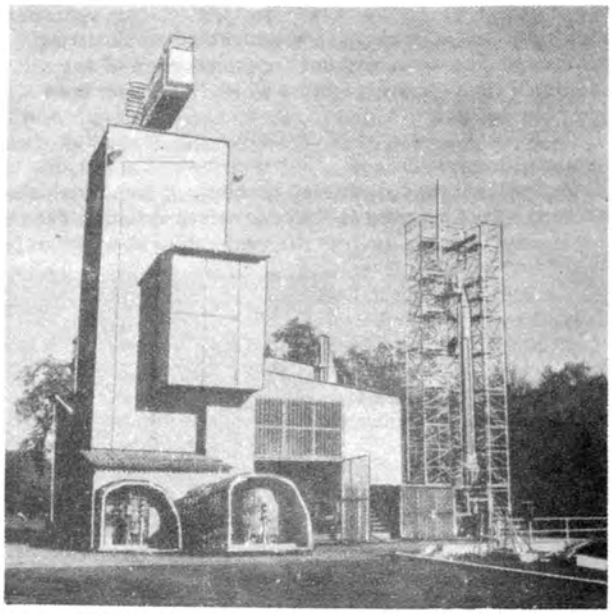
All ground equipment including containers required for fuelling are mounted on standard airline pallets for ease of transportation. Fuelling is continuously monitored through visual data display equipment.

Development Programme

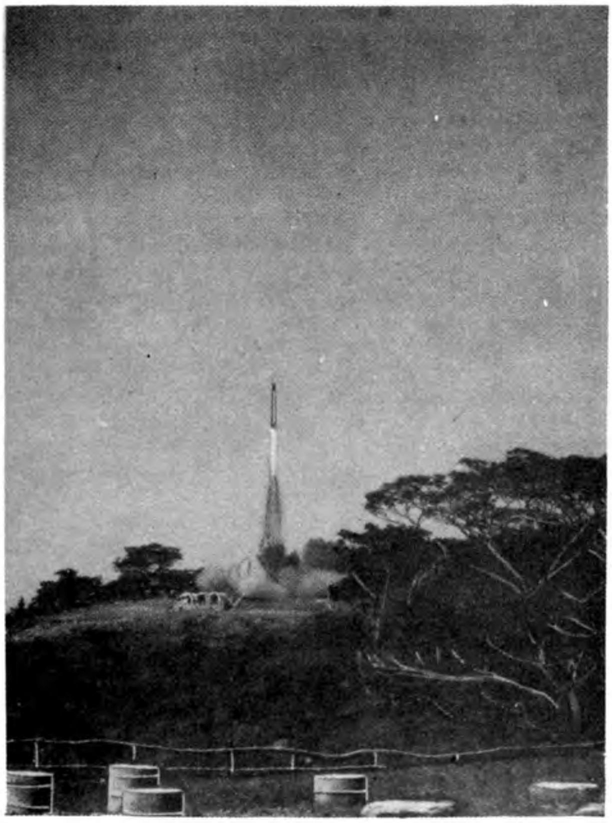
The modular clustering arrangement allows construction of launching vehicles of almost any required size of one to six stages.

The company is already launching test rockets from Zaire. Last May a rocket with partially filled tanks ascended 10,000 metres (32,808 ft.). This represented the first launching of an important German rocket since the V-2 missile of World War II. It is hoped to launch a 200 kg payload to a height of about 100 km. In 1978 the attempt will be made to send a two-stage rocket to double this height with a 500 kg payload.

The first satellite launch attempt is planned for 1979, the same year as the ESA Ariane and NASA Space Shuttle make their maiden flights. OTRAG aims to achieve a 300 km orbit with a 100 kg payload – which is similar to the capability of the US Scout rocket.



All ground equipment including containers required for the fuelling operation are mounted on standard airline pallets for ease of transportation.



Successful launch of the first OTRAG rocket on 17 May 1977 from the company's range in Shaba North, Zaire. The rocket consisted of four tanks and four clustered engines of three tonnes thrust each.

Checkout. The fuelling of rockets is continuously controlled bv means of visual data display equipment.

Much more ambitious space shots are then anticipated. In 1980 the company envisages launching 5,000 kg into a 1,000 km orbit. A year later a 10,000 kg satellite could be placed into a 300 km orbit or 1,500 kg into geo-stationary orbit.

Critics of OTRAG's plans find these objectives highly optimistic (see below).

Launch Range

To achieve their launch centre OTRAG have penetrated the jungles of central Africa to lease from the Republic of Zaire "until the end of the year 2000" a largely uninhabited territory half the size of West Germany which the company proudly asserts constitutes the largest launch range in the Western World.

Progress has been rapid. A 2,100 metre x 40 metres wide airstrip for transport aircraft has been built in six months on a plateau at an altitude of 1,300 metres which overlooks the river Luvua. Nearby is an underground control centre and launch facilities.

Test rockets are flown to Zaire in Argosy transports owned by OTRAG's subsidiary ORAS (OTRAG Range Air Service).

Houses and community buildings for the OTRAG employees are built on the lines of a holiday camp.

The facilities including the control centre on the edge of the plateau have been built using trucks, bulldozers and other equipment owned by the OTRAG subsidiary Stewering and Fils S.p.a.r., which specialises in bridge construction in developing countries, employing its own modular concrete construction methods. The subsidiary also supplies material for railway construction and other civil engineering projects.

Stewering have recently completed a modern steel reinforced concrete bridge over the Lukuga river which has been financed by the Kreditanstalt für Wiederaufbau.

Costs and Reliability

The commercial success of the rocket project will hinge principally upon the ability to launch payloads into geostationary orbit. Much therefore will depend on the ability to achieve precise guidance and control by dependable equipment.

OTRAG insist that their rockets will be highly competitive with other systems. It should cost 30 million DM (£7.5 million, or $13 million) or less than the estimated cost to place a typical payload into geostationary orbit using the NASA Space Shuttle and upper stage.

It must be stated that not all rocket engineers share this optimism. For example, Professor Hermann Koelle – a former project department head for the late Wernher von Braun at the Marshall Space Flight Center, Huntsville, writes:

"The question is, how much money and time would be required for the rocket to achieve the expected performance (i.e. payload in a geostationary orbit) and reliability which would attract a potential buyer.

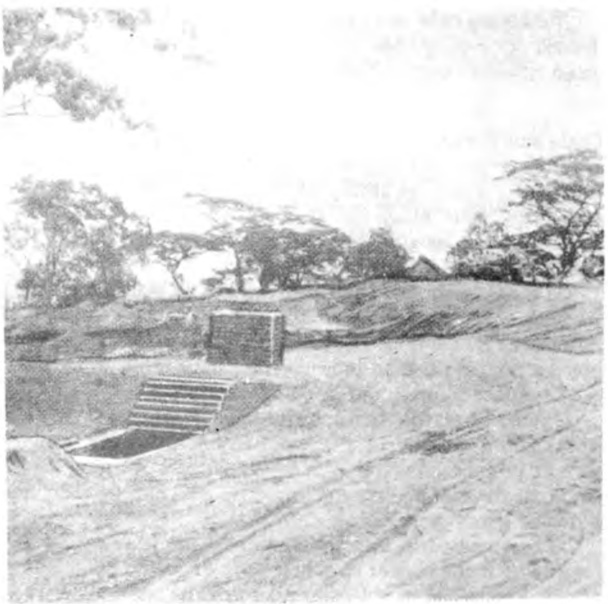
"Whoever knows the basic rules of rocket engineering is aware that the use of cheap fuel leads to excessive fuel consumption and that the use of cheap materials leads to a very high ratio of mass to payload. These two facts lead, in turn, to a large number of stages with engines the number of which reduces performance reliability.

"As the rocket in question is supposed to be cheap there is no money left for extensive ground testing, which is usual in space engineering.

"Anyone capable of checking the performance calculations of the rocket can easily discover that OTRAG's concept of the proposed geostationary mission displays a considerable dependence of the payload on the engineering aspects

The 2,100 metre runway for transport aircraft which OTRAG employees built in six months on a plateau overlooking the river Luvua in the Republic of Zaire. Launch pads and underground control centre are situated near the edge of the plateau.

Rockets are flown to the OTRAG range in Zaire in the company's Argosy transports. The first test vehicle is unloaded ready for the launch of 17 May.



Constructing the underground control centre on the edge of the plateau.

(choice of propellant and materials) which, in practice, means that until the development programme is complete there can be no reliable estimate of what the payload of the multi-stage rocket can be.

"As for the economic arguments, Kayser maintains that he can develop and build a rocket for a geostationary payload in five years with DM800 million, a rocket whose performance, payload capability and reliability, would be of such interest to buyers that he could sell at least three rockets a year for about $10 million each.

"So far this is nothing but an assertion, or hope unjustified by any facts whatsoever.

"Let us suppose the favourable circumstances that the rocket engines and tanks could be produced 'for nothing'. There would still be costs connected with the electrical system of the rocket, the on-board circuitry, the monitoring and flight guidance system, the communications system and other assemblies which nowadays constitute as a rule about 50 per cent of a rocket's production cost.

"Rockets with a performance similar to that assumed by Mr. Kayser are the former Saturn I and Titan IIIC, both of which have developed components in their structures. Today's cost of the electrical, electronic and other equipment is about $10 million per rocket, and it is not to be expected that Mr. K. would either be given these assemblies for nothing or that he could produce them himself at nil cost.

"Therefore, even if he could manufacture the engines and shell at an extremely low cost, and even if he could develop the rocket by 1980, he would be faced with the following situation at that point in time.

"The American Space Shuttle will be able to offer a *successful* launch of a payload of about 2,000 kg into a geostationary orbit with a reliability exceeding 90 per cent for $15 million. Ariane would possibly be able to carry a 750 kg payload into such an orbit with a reliability of, perhaps 75 per cent for possibly $30 million.

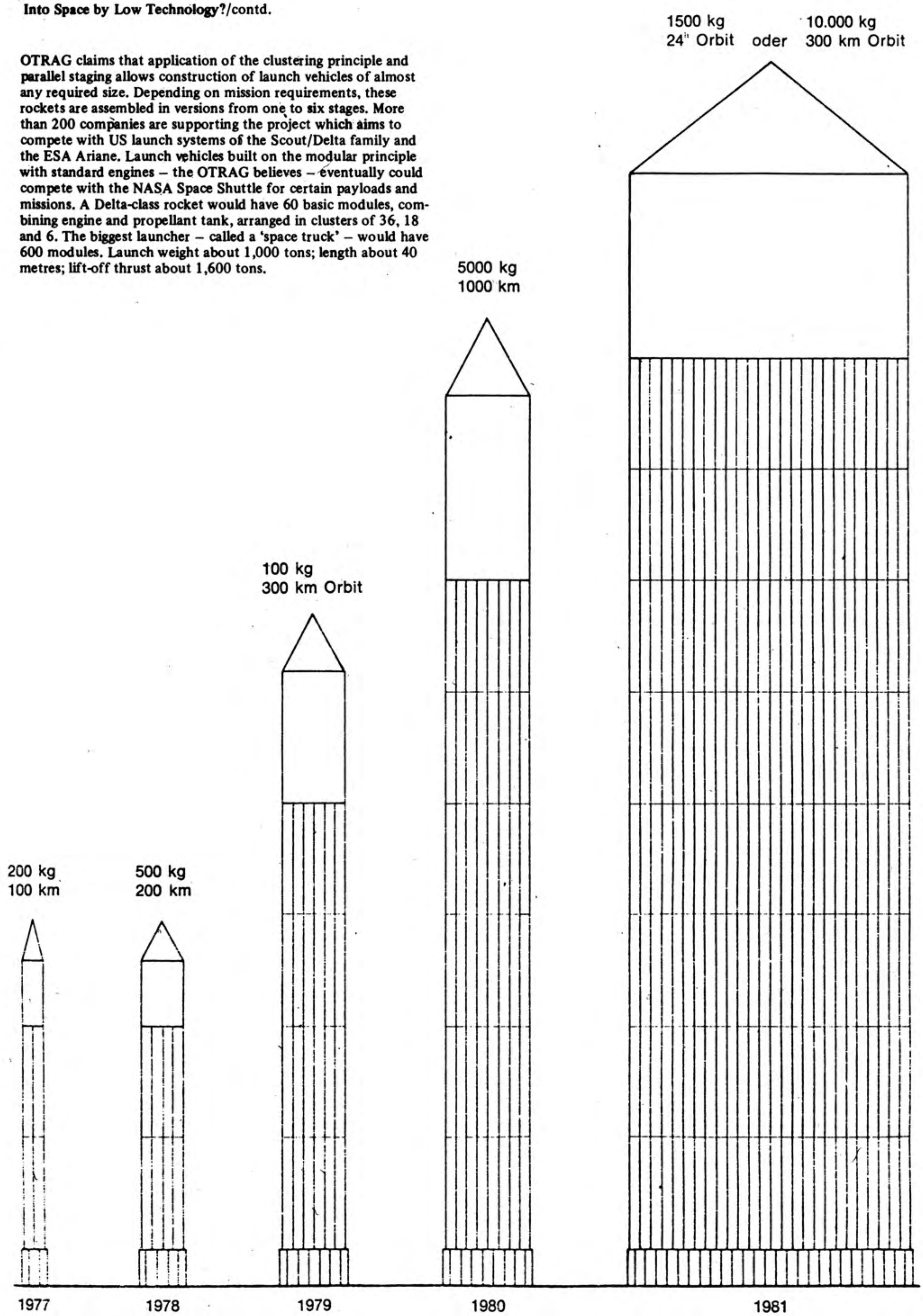
"Even under the most favourable circumstances Mr. Kayser could hope only for a payload of under 1,000 kg with a reliability of less than 50 per cent for $20 million for a "successful launch," meaning two launch attempts.

"The cost is more likely to be $40 million. As his rocket can have merely a low reliability because of its design concept and the development and test philosophy of extreme cheapness, the potential customer has to consider the loss of one payload during the two necessary launch attempts. A payload of this kind costs at least $10 million and probably twice as much.

"This puts the cost of a *successful* launch up to at least

Into Space by Low Technology?/contd.

OTRAG claims that application of the clustering principle and parallel staging allows construction of launch vehicles of almost any required size. Depending on mission requirements, these rockets are assembled in versions from one to six stages. More than 200 companies are supporting the project which aims to compete with US launch systems of the Scout/Delta family and the ESA Ariane. Launch vehicles built on the modular principle with standard engines – the OTRAG believes – eventually could compete with the NASA Space Shuttle for certain payloads and missions. A Delta-class rocket would have 60 basic modules, combining engine and propellant tank, arranged in clusters of 36, 18 and 6. The biggest launcher – called a 'space truck' – would have 600 modules. Launch weight about 1,000 tons; length about 40 metres; lift-off thrust about 1,600 tons.



$30 for the potential buyer and that brings it within the order of the figure to be expected from Ariane.

"In relation to the Space Shuttle, Mr. Kayser's rocket is at an even greater disadvantage as it would transport less than half the payload for twice the price, i.e., be four times worse than the Shuttle which is already being developed and had $5,500 million (1972 value) allocated for it by the Congress for this purpose".

Our own Val Cleaver, asked to comment on the foregoing, replied:

"The broad philosophy advanced by Mr. Kayser and OTRAG is at least arguable. At the present stage in space flight development, one might reasonably attack the problem of improving economy in either of two diametrically opposed ways – a simple, crude, inherently cheap, but heavy and inefficient, expendable "big dumb booster", or the much more refined, efficient, recoverable and re-usable vehicle (the "Shuttle"). Intuitively, one feels that the latter approach will win out eventually, but there might be an interim period, at least, during which there was room for both.

"Whether Mr. K's vehicle will constitute a good example of the former approach is at any rate questionable. From private contacts, I know that it has been widely criticised by competent German industry, as by Professors Hermann Koelle and Harry Ruppe, respectively of Berlin and Munich Universities. These criticisms have included questioning of the validity and consistency of some of the performance claims made, on the basis of actual tests to date. I have no first-hand information which enables me to comment on this aspect.

"However, from a considerable past experience, I can personally comment that the so-called "adiabatic" pressurised feed system will be inherently very heavy and inefficient (as compared with turbopumps), especially for longer firing durations. Also, nitric acid/kerosene, while certainly a cheap propellant combination, and quite widely used in the past, is a notoriously difficult one with which to achieve smooth and efficient combustion especially with throttling.

"One must also add that the large and costly development programmes, with huge staffs and elaborate facilities, employed by such bodies as NASA and Rocketdyne, are *definitely* not without reason. Perhaps they are rather larger and more expensive than they need be, but not to the extent that inexperienced enthusiasts may think.

"Broadly, therefore, I tend to agree with Koelle, as here quoted – except for his alleged statement that the Shuttle will enable a 2,000 kg payload to be placed in a geostationary orbit for a cost of $15 million. If Hermann actually said this, it is almost as unrealistic as anything Mr. Kayser has claimed! The figures for Ariane are more accurate, and on a "per kg" basis, will at least not be much worse than for a "Shuttle/upper stage" combination, as planned at present. They therefore represent what OTRAG needs to beat, and I wouldn't give a dime for their chances of succeeding."

Conclusion

Despite the reservations expressed above, we shall follow OTRAG's progress with interest. Whatever the outcome may be one cannot but admire the company's determination to prove a case for low-cost technology in a very difficult field of technical endeavour.

Acknowledgements

The author wishes to thank Lutz Kayser and his associates at OTRAG for technical information and photographs used in this article. Thanks are also due to the following for comments which were specially invited: Hermann H. Koelle, Director of Engineering, Professor of Space Flight Technology on the Staff of the Technical University, Berlin; and A. V. Cleaver, OBE, head of the Rocket Department of Rolls-Royce Limited, 1957-1973.

MILESTONES

Continued from page 1]

at 66.4 deg. First to announce the test was US Department of Defense which assumed a successful interception although there was no explosion during the close pass. Cosmos 961 re-entered the atmosphere after about 0.78 day, according to RAE.

26 People's Republic of the Congo becomes 100th member of Intelsat.

28 NASA announces that a retrievable, reusable, low thrust stage – called a Teleoperator Retrieval System (TRS) – is being developed at the Marshall Space Flight Center. Martin Marietta Corporation will be responsible for vehicle integration. An astronaut will deploy the TRS by remote control from the Space Shuttle cargo bay. The TRS, which will have a TV-eye, will transmit images to a monitor screen in the Shuttle to facilitate remote control operations. The TRS can also be manoeuvred to higher orbits and return to the vicinity of the Shuttle Orbiter using its own guidance and computer system. When back in TV range, the astronaut will return the vehicle to the cargo bay. The TRS "will first be used for a Skylab orbit adjust mission on an early OFT flight. This mission is planned to adjust the Skylab orbit to permit future Space Shuttle revisits or to provide a controlled re-entry of Skylab into an open ocean area." The Teleoperator will incorporate a docking problem on the forward end for attachment to the space station's axial docking port. If Skylab is still in orbit, the attempt will made on the fifth Shuttle flight in February 1980. Skylab's orbit currently ranges between about 400 to 420 km inclined at 50 deg to the equator.

28 British sounding rockets feature in combined Anglo-German rocket campaign at Andoya, Norway between October and December to investigate Northern Lights and related phenomena. Campaign features no fewer than 51 experiments carried by four Skylark 12's launched by Germany's DFVLR and three Skylark 12's, a Petrel and four Fulmar rockets launched by UK Science Research Council. Skylark 12, built by British Aircraft Corporation, Electronic and Space System's, will lift scientific payloads up to 400 lb. (181 kg) to heights of 500 miles (804 km). The smaller rockets Petrel and Fulmar are built by Bristol Aerojet.

November

6 NASA issues tentative conclusions about recent space failures at Cape Canaveral: *Delta 3914* rocket carrying ESA Orbital Test Satellite, rupture of No. 1 Castor IV booster's casing leading to mechanical or thermal damage of launch vehicle structure. *Atlas-Centaur* carrying Intelsat 4A, local overheating, perhaps in Atlas booster section, led to mainstage explosion.

FROM MOLNIYA TO EKRAN

By Theo Pirard*

Our Belgian correspondent Theo Pirard was recently in the Soviet Union where he met officials of the Ministry for Postal Services and Telecommunications including Alexander M. Varbansky, chief engineer in the Space and Radio-communications Department. During his visit he was able to clear up many questions concerning the development of satellite communications in the Soviet Union, including the use of direct-broadcasting satellites which now extend links between Moscow and the Soviet Far North. The author wishes to thank the Novosti Press Agency for assistance in the preparation of this report part of which appears also in 'Unda-Documentation', the Belgian quarterly review of the International Catholic Association for Radio and Television.

Introduction

The Union of Soviet Socialist Republics extends over some 22,400,000 square kilometres and includes more than 255,700,000 inhabitants. The territory is covered by 11 time zones out of 24 covering the entire planet; when day breaks at Vladivostok in the far east, night has just fallen in Moscow and Leningrad.

The population is unevenly scattered throughout the USSR with denser regions of population in the western and southern regions including the Ukraine, Moldavia, Caucasus and Central Asia. This uneven spread of population creates an urgent need for good communications.

Early Developments

In the face of this need, a first attempt was made to cover the whole of the USSR by television. The plan was to broadcast from a huge transmitting tower to a network of smaller relay stations. In 1967 an architectural challenge was met in the shape of the 553 m tall TV Ostankino Tower in Moscow which now broadcasts within a radius of 120 km (74 miles).

The Molniya Project

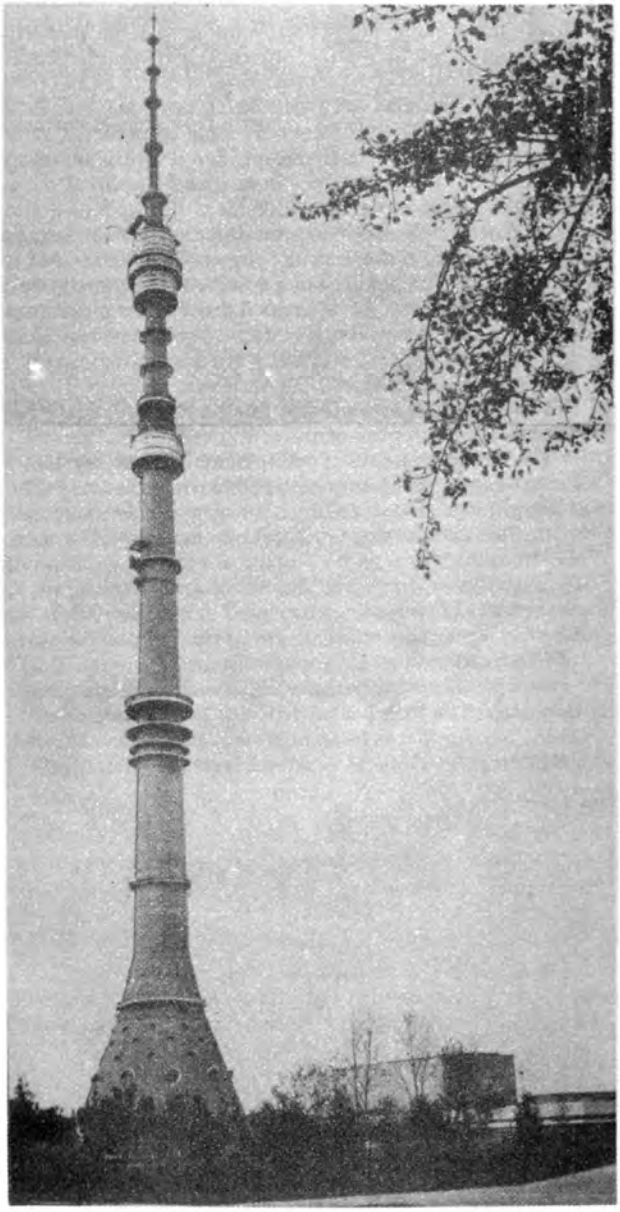
On 23 April 1965, the official news agency *Tass* announced the launching of a communications satellite by the name of Molniya (Lightning). The satellite was stabilised on three axes and similar in shape to the first Soviet lunar and interplanetary sondes. It travelled around the Earth in 12 hours on an elliptical path between 538 and 39,300 km at 65.5° inclination during which it passed over the Soviet Union for about nine hours. During this period it was used for communications in Soviet territory.

If communication is required throughout the 24 hours, then three Molniyas must be used which pass over the USSR in succession.

To maintain a continuous link with the Molniyas, a network of ground terminals – called Orbita – was set up near big cities with parabolic aerials of 12 m (39.4 ft.) diameter which allows reception of TV pictures, telephone calls and telex. The stations could also transmit telephone and telegraph messages *via* the satellites.

By the end of 1976 no fewer than 35 Molniya satellites were in orbit as the world's first domestic satellite service managed by the Postal Services and Telecommunications of the USSR.

* *The author is space news editor of the Belgian monthly 'Aviastro'. Original of this report in French; translation by Sr Mary Antonia Varese, O.S.M.*



The TV broadcasting tower of Moscow-Ostankino which stands 553 metres.

All photos Novosti Press Agency

Today, however, the Molniya 1 series belongs to an obsolescent technology though it apparently still has certain military applications.

Molniya 2

Molniya 1 was used mainly for relaying telephone calls – and had a power output of 20 watts but the relay of television at 40 watts was not entirely satisfactory and TV transmissions were carried out only intermittently. A new type of satellite, Molniya 2, was brought into operation on 24 November 1971 although it pursued the same type of elliptical 12 hour orbit. Many others of the type have since

appeared to maintain a regular service.

The newer system employs relay stations of greater capacity and which function at higher frequencies (6 GHz) in comparison with the first Molniya 1 which operated in the 1,000 MHz band. Satellites of the Molniya 2 series have directional antenna making possible communications with specific regions.

From the beginning the series has been associated with the Intersputnik network of international communications which allows the Soviet Union to be in direct contact with the Eastern Socialist countries, Mongolia, and Cuba. Orbita stations of this extended network were constructed at Prague, Oulan Bator, near Havana, and recently near Sofia.

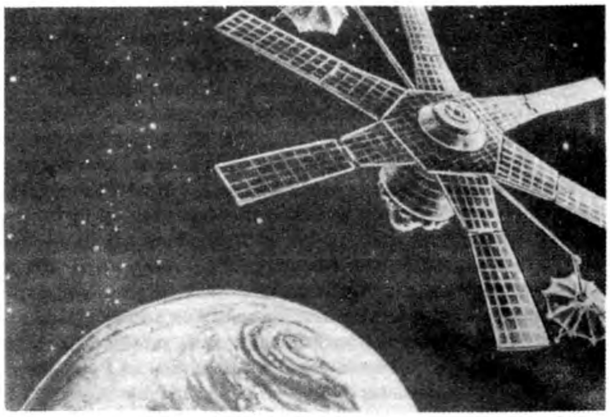
Molniya 3

When the volume of communications increased, especially with the advent of colour television – the SECAM III system – the Soviets needed a still more functional satellite system. The first of the Molniya 3 family was launched on 2 November 1974 which, like its predecessors has a 12 hour orbit. The sixth satellite of this series was put up on 28 December 1976.

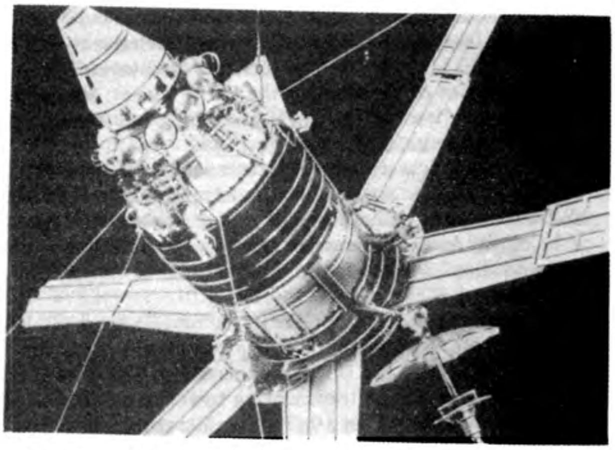
The Molniya 3 series is now gradually supplanting the first two Molniya systems.

The Molniya family (types 1, 2 and 3) share certain characteristics. They employ satellites described as "slow moving" because they take 12 hours to go once round the Earth. The antennae of the Orbita ground terminals must be able to follow them with accuracy as they move in the sky. These powerful Orbita stations are designed to operate up to an angle of 62° above the equator. The satellite-Orbita linkage makes possible communications throughout the entire USSR *via* medium-sized ground terminals.

Four Molniyas are necessary to ensure uninterrupted daily links. The Molniya capacity for television is overloaded because the system must relay programmes from Moscow to the whole of Siberia. Three out of four programmes from the main TV studios in Moscow (five are planned for the future) are thus relayed to various regions. This is not without its complications. Programmes have to be broadcast as evening begins in each region. To accomplish this, the Soviet territory has been divided into five broadcasting zones, from the Far East (Kamchatka and Vladivostok) to Byelorussia in the west.



Artist's impression of Molniya 1 satellite over the Northern Hemisphere.



Molniya 1 satellite on exhibition.

A station of the 'Orbita' network which operates in conjunction with Molniya and Raduga communications satellites.

Thanks to Molniya, especially Molniya 3, the same programme is broadcast on one channel (No. 4) during five successive sessions per day. The first reception area is the Far East; the other four follow in turn as they come nearer in time to Moscow. One major inconvenience affecting programme content is that the Far East does not get the latest news. The USSR Central Television Committee currently is grappling with this problem.

A portable ground station was deployed by the Soviet Union in the early 1970s which almost certainly has its military counterpart. The terminal, which has a 7 m (23 ft.) dish and provides a link with both Molniya and Raduga satellites, goes under the name of MARS, the abbreviated form of Malaia Retranslatsionnaia Strantsua. The complete station can be packed into three containers 5 m long, 2 m wide and 2.5 m high and is air-transportable.

Soviet television employed a MARS when reporting directly from abroad. One such occasion was Leonid Brezhnev's visit to India in November 1973 when a station

was set up in New Delhi in three days and relayed pictures directly to Moscow.

First Soviet Geostationary Comsats

The Russians have been trying to correct the overloading of the Molniya system by putting satellites into geostationary orbit tracing a 24 hour path immediately above the equator. After making tests with a Cosmos 637 prototype, Molniya 1-S (Statsionar) was put into orbit on 22 December 1975 and subsequently stationed above the Indian Ocean. The new system goes under the name of Raduga (Rainbow).

The second example of the Raduga series was launched on 11 September 1976.

We are still ignorant of the design features of the Radugas but we do know that they operate on the same frequency as the most recent Molniyas, at between 8 and 10 watts. They are capable of relaying one television channel and 10 channels carrying 1,000 telephone lines.

The 'fixed' nature of the Raduga orbit eliminates the need for costly movable antennae. But one drawback from their enforced placement above the equator is that it is more difficult to communicate with the Soviet Far North. For this reason the Radugas do not replace the Molniyas but rather complement them.

By 1980, the year of the Olympic Games in Moscow, Intersputnik plans to have Raduga 2 class operational satellites over the Indian, Pacific and Atlantic Oceans thereby ensuring its own system of global communications. The first of these was launched on 23 July 1977.

Ten Radugas are expected to have been placed in geostationary orbit by 1980. Broadcasting on frequencies of 4-6 GHz, their programmes will be picked up by stations equipped with 9 m (29.5 ft.) antennae.

In spite of the attempt to structure the three Molniya systems and the Raduga group to encompass the four TV channels carrying programmes originating in Moscow, these channels cannot be received everywhere in the USSR. Approximately 80 per cent of the population is able to pick up the first channel; 55 per cent the second and up to about 20 per cent the third and fourth.

This still leaves one-fifth of the population without television, for the most part, isolated in the vast territories of Central Siberia. The great importance which Moscow attaches to the development of this region, so rich in minerals and fossil fuels, is well known. So Soviet technology is now being directed towards getting television to the peoples of this remote area.

Direct-Broadcast Satellites

The "last word" in satellite technology is the creation of a system for broadcasting television directly to local antennae. To meet this requirement, the Soviets launched a prototype satellite equipped for this purpose. Long before it was launched, it was given the name Statsionar T – T for television.

Statsionar T was launched from Tyuratam on 26 October 1976. Its official name is now Ekran (Screen). Although it took up station at longitude 99°E above the equator on 11 November, its function is completely different from that of Raduga.

Ekran is an experiment in the direct transmission of a TV programme to isolated communities, in this case the region between Novosibirsk and Irkoust, to the north-west of Mongolia.

The geostationary satellite Ekran employs a 200 watt transponder and carries a large panel with 90 helical small antennae. It is broadcasting one TV programme on the 702-726 MHz frequencies, currently used by conventional TV transmissions, so that suitably amplified television sets in private homes and local networks can pick up programmes by rooftop antennae.

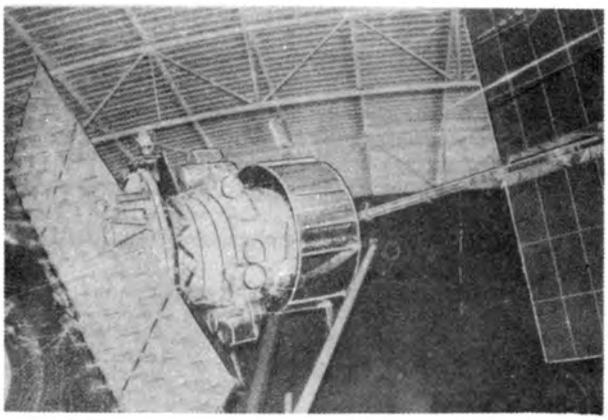
The present Ekran system is experimental but tests are

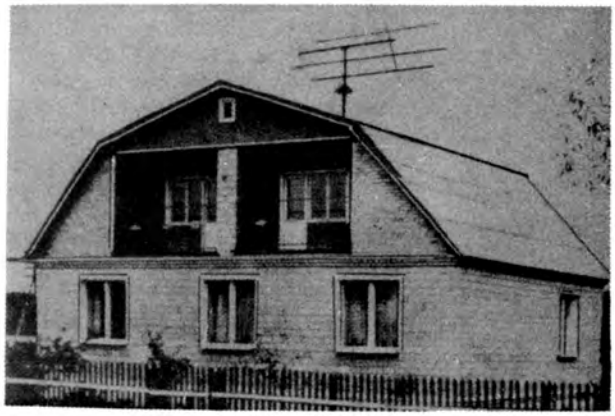
Soviet Satellites for Civilian Telecommunications.

Satellite	Type	Number 30 Sept. 1977	Frequencies (uplink/downlink)	Objective
Molniya • pursues elliptical 12-hour orbit, between 540 and 39,300 km (early Type 1)	1	38	800-1,000 MHz 3.4-4.1 GHz	Establish a domestic telecommunications network by means of satellites. Launched by A-2.
• at angle of 65° to equator (early Type 1)	2	17	6.2-5.7 GHz 3.4-3.9 GHz	Widen the Soviet network to include communist world through the intermediary of Intersputnik. Improved satellites but already out-stripped by demand. Launched by A-2.
	3	7	6-6.2 GHz 3.6-3.9 GHz	Meet increased demand, especially for television. Launched by A-2.
Raduga (or Statsionar S) • geostationary	1	2	5.7-6.2 GHz 3.4-3.9 GHz	Improve upon the Molniya system of domestic communications. Launched by Proton D.
• pursues circular orbit at about 36,600 km • orbiting above equator • broadcasting at 8 and 10 watts	2	1.	5.7-6.2 GHz (?) 3.4-3.9 GHz (?)	Establish global network for Intersputnik. Seven satellites of this type planned between now and 1980. Launched by Proton D.
Ekran (or Statsionar T) • geostationary • television only • broadcasting power 200 watts	1	1	6.2 GHz 702-726 MHz	Provide direct-broadcast links with isolated communities. Launched by Proton D.

Molniya 1-S, launched 29 July 1974 into geostationary orbit by Proton D launcher was Raduga forerunner.

Left, diagram of Ekran system tested by the USSR Ministry of Communications. The geostationary satellite allows one TV programme to be transmitted directly from Moscow to regional stations or domestic receivers in Central Siberia.
Below left, replica of the Ekran satellite. Three-axis stabilised, it has two independant panels of solar cells and a special antenna with 90 spiral elements.
Below right, a house in Siberia equipped for the direct reception of a TV programme re-broadcast by the satellite Ekran.
Bottom left, antenna, TV set and converter required for the direct reception of television in the Soviet Far North from the satellite Ekran.





reported to have been highly successful. Local relay stations have been set up to serve up to 10,000 people and there are also automatic receivers which serve up to a few hundreds.

Thus, for the first time areas in the Soviet Arctic North and Siberia have been embraced by Moscow-based television, which was beyond the coverage of the Molniya/Orbita system.

The Soviets intend to extend the use of international communications and of high frequency broadcasting satellites and are working closely with the International Telecommunications Union in the allocation of the spacecraft and of their frequencies.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

PIGGYBACK FORERUNNER

Stacked on top of its Boeing 747 'mother', the Space Shuttle Orbiter *Enterprise* looks like a back-breaking load for the Jumbo Jet. One of the 747 pilots characterised the stack as "the world's largest biplane."

Nasa officials admit it was a former British project – the Short Mayo Composite Aircraft – that inspired confidence in flying the Shuttle in this unusual combination.

The 'mother' flying boat, called *Maia* carried a smaller seaplane – *Mercury* – on a pylon and made the first separation flight on 6 February 1938. In July of that year, the twosome flew from Foynes, Ireland , to launch *Mercury* on a flight nonstop to Montreal with a load of mail and newspapers.

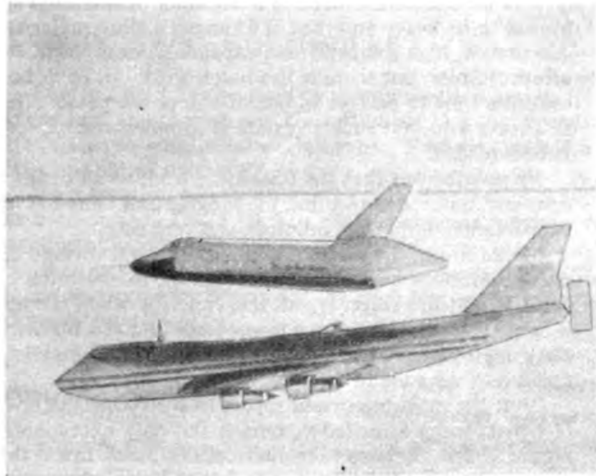
We were reminded of these events by Air Vice Marshal D. C. T. 'Pathfinder' Bennett (retd.) following an article on the Boeing 747/Space Shuttle combination:

> He comments: *"I am delighted that you mentioned the Short Mayo Composite Aircraft but my purpose in writing is to express my mild regrets that you failed to point out to the British Public and the world that Mercury, the top half of the Short Mayo Composite, not only carried the first paying pay-load across the North Atlantic but also established a world's long distance Seaplane record from Scotland to South Africa which stands as the world record to this day."*

Air Vice Marshal Bennett was too modest to add that in 1938 he was awarded the Johnston Memorial Trophy by GAPAN for the first commercial east to west crossing of the North Atlantic in Mercury, upper component of the Mayo Composite Aircraft. His long-distance record for seaplanes (Dundee in Scotland to the Orange River in South Africa) was indeed a milestone. The flight covered a distance of 5,997 miles.

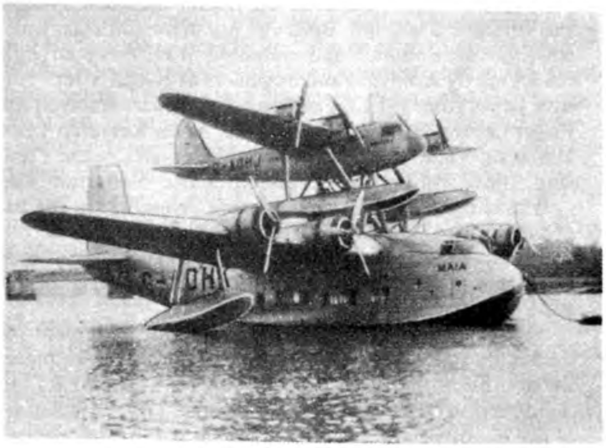
Maia and *Mercury* were operating between Southampton and Alexandria, Egypt, when World War II broke out.

Mercury was scrapped in 1941 after serving with a Dutch seaplane squadron attached to the Royal Air Force. *Maia* was destroyed by a Luftwaffe bomb on 11 May 1941, while moored in an English harbour.



Flying the Space Shuttle 'Enterprise' from the back of the Boeing 747 'mother' has been an important milestone to a new age of Astronautics (see page 38).

National Aeronautics and Space Administration



Forty years ago the 'piggy back' concept of flying one aircraft from another was convincingly demonstrated in Britain by the Short Mayo Composite Aircraft.

EXTENDABLE ROCKET NOZZLE

The first test at operational pressures and temperatures of an extendable exit cone (EEC) system for ICBM nozzle application has been successfully carried out by the Chemical Systems Division (CSD) of United Technologies.

Using nested cones of an advanced composite material, the CDS-funded system underwent a 23-second static firing on a test motor loaded with 21 per cent aluminium, 90 per cent solids HTPB propellant. It operated at 1600 psi under simulated altitude conditions at the Air Force's Rocket Propulsion Laboratory, Edwards AFB, on 2 June 1977. Inspection of the hardware after the test showed absolutely no anomalies. "It looked brand new," said one engineer.

Eugene Roberts, division vice president and head of the MX Program Office said, "We are naturally elated at the outcome of this test. We have proven the integrity and reliability of the system under conditions close to those which would be experienced during an operational mission. We're now looking forward to the next test which will see the system undergo deployment of the cones on motor ignition and a firing duration of 65 seconds."

In the 2 June test the nested cones were extended and locked into position with an innovative latching mechanism. In the subsequent test the system employed a "two-in-one" actuation system to extend the nozzle exit cones on motor ignition. A rotary actuator at the base of the nozzle gives low initial deployment force to avoid radial loading of the nozzle's cones. Telescoping tubes supply the force for final deployment. These tubes can then be retracted.

The recent test was preceded by system configuration studies, deployment and latching mechanism evaluations and subscale bench tests in late 1976.

"Use of an extendable nozzle exit cone can give large performance gains for length limited missiles; as much as three to four per cent in propellant specific impulse or some

eight to ten seconds," Michael LeFebvre, manager of CSD's EEC development programme, said. "A great deal of study convinced us that the nested cone was the way to go both from the standpoint of reliability as well as cost.

"We tried a rolling metal system which worked but it proved to be heavy and required tungsten alloy materials due to new, high temperature propellants. Composite cloth offers promise, but there is too much work to be done and too little time to perfect it. Use of composite petals offers an answer also, but such a system is complex and expensive," LeFebvre said.

He pointed out that the CSD system solves all of the problems encountered with other extendable exit cones. It is light-weight, simple, economical, and reliable.

"In addition, the CSD system will fit the truncated cone storage envelope of an MX and is suitable for both the second and third stage. It will also function when the motor is fired to separate it from a lower stage and can survive early deployment or late deployment at lower dynamic pressures," he added.

"But the most important aspect of the recent test is the fact that, tc my knowledge, ours is the only extendable nozzle system that has been successfully tested in anything like an operational environment, using lightweight hardware."

ION DRIVE FOR INTERPLANETARY FLIGHT

The ion drive propulsion system has been selected over the solar sail concept as the propulsion system for interplanetary automated shuttle use within the Solar System in the 1980s and beyond. Both the ion drive and solar sail concepts were studied and evaluated in various configurations for a year by scientists and engineers at NASA's Jet Propulsion Laboratory (JPL), Pasadena, California; Marshall Space Flight Center, Huntsville, Alabama; Ames Research Center, Mountain View, California; Lewis Research Center, Cleveland, Ohio, and Langley Research Center, Hampton, Virginia.

The choice of ion drive was made primarily on the basis of lower risk and greater future growth potential.

An ion drive spaceship would employ a cluster of mercury ion engines and use power generated by large solar cell arrays that convert sunlight to electricity.

Mercury ion rockets have been under development for a decade by NASA. In 1969 ion rocket engines were placed in Earth orbit in the Space Electric Rocket Tests (SERT) under the direction of Lewis Research Center. These forerunners of the ion drive propulsion system are still being operated regularly in space.

For the ion drive concept, Lewis Center and two contractors, Hughes Research Laboratory, Malibu, California, and TRW Systems, Redondo Beach, California, contributed rocket engine designs. JPL and Marshall Center concentrated on the high powered solar arrays. The study was headed by Dr. Kenneth L. Atkins of JPL.

The first possible use of ion drive propulsion could be for a comet rendezvous in the 1980s if NASA selects such a mission from among several possible options.

ROBOT 'SPACE SPIDER'

A robot cousin of 'the spider' may one day spin a metal web in space when man starts building large space structures, writes Dave Dooling. A first picture of the concept appeared on the cover of our September 1977 issue.

The "space spider" was invented by Dwight Johnson of Marshall Space Flight Center. Johnson is responsible for teleoperators – remote controlled mechanical arms.

Several automated or semi-automated systems are under study for ways to construct large space structures (the phrase usually means solar power satellites or space factories). Johnson said he conceived the space spider after attending a conference on a different system.

"I got to thinking," he said, "in comparison to the size and the thickness of the material, the structure would have the same structure as a spider web." But unlike an Earth spider, the space spider would have to work from the inside out because, "we have no skyhooks in space" on which to anchor the spider's work.

In models built by Johnson, the spider is a four-legged creature with a box on top and a small platform below. The web is spun from rolled metal carried on the box part, as the web grows in a spiral with the spider travelling on the material it has just laid down.

The rolled metal – most likely aluminium, Johnson said – will be like a stamped blueprint. As the metal passes through the assembly unit, two upright supports are bent out of the centre of the metal, and their ends spot-welded to the web below. The edges of the strip are crimped to form a shallow "U" shape for strength and for the spider's feet to grasp. Then the spider moves forward another unit and starts again.

A laser on the spider would watch a special mirror in the centre of the web so the spider would stay on track. Special operating instructions could even be stamped into the edge of the web's material.

Preliminary figures show that a spider moving at one foot per minute could spin a web 2,132 ft. wide in half a year. A solar power satellite using a collector that size could produce 33 megawatts of electricity a year. But there are a lot of "to be determined" items there, Johnson said, including material thickness, structure size and speed of construction.

The web described here would be a spiral that increases by the same thickness each time, like the grooves of a long-playing record. Johnson said the spider could be programmed to spin virtually any shape desired simply by ordering the spider's legs to change height or giving it a different starting shape.

"You could conceivably spin almost squares or rectangles," Johnson said. It could spin spheres and cover them so they would be air-tight, although that is a distant application.

"All you've got to do is provide the material and the power to the spider."

A variation on the spider could cover the spiral with solar cells, again from a roll it carried.

The advantages over other systems being studied are ease and simplicity, Johnson said.

"I visualise that all the construction is integrated into one activity," he said. "You've got your complete operator in one machine," with no need to worry about remote manipulators. The even expansion of the design would make it easier to stabilise.

Little more than the concept has been developed to date; requests for quotations on studies have been made, and contractors should be developing the idea further in the coming months.

"The idea is so new that there won't be any real funds made available until we get a feel for its potential practically," Johnson said.

VIKING AID TO BLADDER FUNCTION

Space technology is playing a major role in the development of an improved, surgically-implanted prosthetic urinary sphincter for patients who have lost muscular control of bladder functions through injury or disease.

In a joint effort, NASA and industry are developing a

simple, reliable prosthetic urinary sphincter with external controls which uses a miniaturized valve originally developed for spacecraft such as Viking.

"Our goal is to develop and test a prosthetic sphincter that is reliable and easy to operate and to make it commercially available within three years," said John Richardson of the Technology Utilization Office at NASA's Marshall Space Flight Center.

Many victims of accidents or diseases such as diabetes mellitus, cerebrovascular disease, Parkinson's disease and multiple sclerosis lose control of their bladder functions. Present corrective methods require these patients to use external collection devices, indwelling catheters or a prosthetic urinary sphincter.

Today's sphincters are complex and difficult to operate, Richardson explained. Most contain three or four valves and valve malfunction accounts for a significant number of failures. "The Marshall Center became involved in the possibilities of development of such an improved prosthetic device at the recommendation of the NASA Biomedical Applications Office at the Research Triangle Institute in North Carolina," Richardson said, "because of our expertise in miniature valve system design, manufacturing, assembly and operation."

Marshall Center's Technology Utilization Office is directing the project. It will select a contractor to complete sphincter design, sponsor animal tests, conduct clinical trials and prepare documents for the Food and Drug Administration's approval. The contractor would also manufacture the sphincter commercially.

The company awarded the contract will select one or more university medical schools to perform many of these animal tests and a subcontractor to furnish the miniature sphincter valve.

Early designs of the improved sphincter involve a cuff, a single control valve and a reservoir system. The cuff, or collar, will be surgically implanted around the urethra to close the urine passage when inflated. The control valve and the reservoir system will also be implanted for external control.

The improved sphincter will allow the bladder to fill and be emptied rapidly every three or four hours, exercising the bladder muscles and reducing risk of infection. Kidney failure resulting from bladder infection is now a major cause of death among patients who have lost normal control of bladder functions.

EXOSAT X-RAY EXPERIMENT

British Aircraft Corporation will be deeply involved in a new X-ray space experiment to probe into the physics of pulsars, neutron stars, black holes and other little understood celestial objects. Under an ESA contract BAC's Electronic and Space Systems – in partnership with the firm's United States sub-contractor LND Incorporated – will design and build the detectors and mechanisms of the 'medium energy' experiment to be carried by the X-ray satellite EXOSAT. The experiment will measure X-rays in the energy range 1-50 KeV by the use of sealed proportional counters containing Argon and Xenon gases. A part of the experiment will be a mechanical arrangement to enable the detectors to be commanded from the ground to diverge in two groups in steps of 3 arc minutes to an accuracy of one arc minute from their nominal pointing direction.

The experiment will be used in two ways – one free pointing, to study the time structure, time variability and spectrum of the X-ray emitting sources, and the other in the Moon occultation mode, which will permit the X-ray sources to be located with an accuracy of one arc second. The orbit of EXOSAT has been chosen to be highly eccentric with its major axis at right angles to the Moon's orbit plane, to make the most of the opportunities for useful occultation.

SPERRY REACTION WHEELS

Sperry Flight Systems are to supply reaction wheels for gyroscopic stablisation and control of the U.S. Air Force DSCS III communications satellite and NASA's Maximum Mission (SMM) spacecraft.

Four reaction wheels weighing 5.5 lb. (2.5 kg) each will be used on each DSCS III. The SMM spacecraft is being developed by the Goddard Space Flight Center. It will use Sperry-supplied NASA standard reaction wheels similar to those developed by Sperry for the High Energy Astronomy Observatory (HEAO).

ORIGIN OF LIFE

Scientists at NASA's Ames Research Center have uncovered an important factor in understanding the origin of life on Earth.

The research shows how building blocks of life may have been collected and organised on the shores of the primitive oceans by "natural catalysts" found widely on Earth. This could have been a key step in the chemical evolution of the first living organisms.

The experiments demonstrate how two basic types of life molecules (amino acids, the building blocks of protein, and nucleotides, the building blocks of the life-directing DNA molecule) might have been concentrated in the primitive oceans. The research also shows how non-living amino acids can be selectively destroyed, and how life-related amino acids might have linked together in these ancient oceans into the chains needed to make living cells.

The manner in which random collections and small amounts of life-building blocks could have concentrated to eventually produce living organisms has been a longtime mystery to biologists.

Team leader for the work was Dr. James Lawless of Ames Center along with Dr. Nissim Levi, a National Research Council fellow from Israel working at Ames. Their collaborators were Dr. Daniel Odom, now at the University of Houston, Kristi Kjos and Randy Mednick, both students at the university of Santa Clara, also working at Ames.

Most scientists accept the theory that life began by chemical evolution on the shores of the primitive ocean. The theory says that various forms of energy – such as lightning, heat and ultraviolet radiation – converted the abundant, carbon-maintaining ammonia, methane and water of the primitive Earth into building blocks of life (organic molecules). These molecules, according to the theory, then joined together into ever more complex molecules until a molecule or group of molecules appeared which could replicate itself. This was the first living thing.

In recent years, many scientists have performed a very large number of chemical evolution experiments. These have produced most of the basic life molecules (including amino acids and nucleotides) in small quantities, by applying electrical discharges or other energy releases to ammonia, methane and water. But until now scientists have been unable to explain how the life building blocks in the primordial oceans were organised.

The newly found mechanism involves substances which would have been common on the shores of the primitive oceans – metal clays. Clays had to be widely spread on the primordial Earth and ocean shores; and, by definition, all clays contain metals.

Metal salts would be found in the oceans. When low concentration solutions of amino acids were mixed with the commonplace metal clays, Dr. Lawless's team found that all clays attract amino acids (of which there are about 1,000 different kinds) out of solution. One metal clay (containing nickel) preferentially attracts the 20 amino acids which make protein, the main structural ingredient of living cells. Nickel clay is a very abundant Earth material. Of eight metal clays tried, only nickel clay does this.

Dr. Levi reported that the other clays destroy non-protein forming amino acids faster than protein amino acids. Thus, a realistic mechanism for the concentration and selection of the life-forming amino acids has been found.

Experiments simulating tidal action on the clays (i.e., dry an amino acid solution, warm it, wet it again and repeat the process several times) produces chains of amino acids (eight amino acid molecules linked together, so far). Presumably, time would produce the far longer chains found in life.

A metal clay had a similar effect on the building blocks of DNA. (The very long chain DNA molecule in every living cell, including human ones, contains a blueprint of the entire organism).

DNA building blocks are concentrated by zinc clays. Only the zinc one, of the nine metal clays tried, did this.

A further significant fact is that zinc is known to play an important role in the enzyme, DNA polymerase, which performs the task of linking DNA building blocks (nucleotides) in living cells. Enzymes are supercatalysts which drastically speed up many life processes.

X-RAY NOVA

An X-ray nova – a gigantic star whose X-ray emissions increase violently over a period of time, then return to normal – near the centre of our Galaxy has been optically identified by ground observatories based on precision location information provided them by X-ray sensors aboard NASA's Earth-orbiting High Energy Astronomy Observatory (HEAO 1).

HEAO 1, launched on 12 August, is the first in a planned series of three unmanned orbital observatories designed to provide scientists with a capability to study X-rays, gamma rays and cosmic rays emitted by stars and star-like objects throughout the Universe. The Marshall Space Flight Center manages the HEAO programme under the direction of Dr. Fred A. Speer.

The newly-found X-ray nova has increased its emissions by perhaps 500 to 1,000 times its normal luminosity, according to Dr. Daniel Schwartz of the Smithsonian Astrophysical Observatory, Harvard University, one of the HEAO 1 experimenters.

Dr. Herbert Friedman of the Naval Research Laboratory, Washington, D.C., another HEAO 1 experimenter, stated that the X-rays are believed to be 10,000 times stronger than all the combined radiation pouring off the Sun. The nova, located in the constellation Ophiuchus adjoining Sagittarius in Earth's northern skies, was first detected by a British satellite, Ariel 5 which, however, did not have the capability to locate the object precisely enough for Earth-based telescopes to look for it. When the sky-scanning HEAO 1 moved into a position to observe that region, more precise location data were gathered by its sensors, and made known to ground observatories.

According to Carroll C. Dailey of the Marshall Center, optical telescopes in both Arizona and Australia were able to locate an extremely dim (18th magnitude) star, at the given location, which had not been seen on photographic plates exposed a few weeks earlier. "This means, of course, that the star has increased in the visible light spectrum as well as the X-ray thus adding confidence in the identification," Dailey pointed out. This is only the fourth instance of an X-ray nova being optically identified with a visible star by looking for it with ground-based telescopes using location data from X-ray detector satellites.

"Scientists still don't know for sure what causes an X-ray nova, " he said. "They postulate it could be a binary source, where there's one star orbiting another one, and from time to time a large amount of matter is pulled by gravitational attraction into the nova from its twin, causing the nova to flare up. It's a very complex operation. One of HEAO's objectives is to try to unravel some of these puzzles."

Discovery of the nova is considered by astronomers to be a very significant finding, Dailey said. "This is exciting to us because this is exactly what HEAO was supposed to do. We hope to make many such identifications, since HEAO has much more capability in this regard than any other satellite ever orbited before."

Approximately 300 X-ray sources in the sky were known to astronomers prior to HEAO 1, he said. "We hope, with the use of this highly sensitive observatory, to eventually increase that number by a factor of 10 – that is, up to about 3,000."

MOTHER-DAUGHTER SATELLITES

The two spacecraft launched by a single Delta 2914 rocket last October as part of a cooperative programme by NASA and ESA are continuing to yield vital data on the way in which the Sun controls the Earth's near space environment. Called International Sun Earth Explorers, the mother-and-daughter satellites were launched into elliptical Earth orbits which range in distance from 280 km (174 miles) to 140,000 km (87,000 miles).

The launch had been delayed from 13 to 22 October pending the findings of the panel set up to investigate the loss of the Delta 3914 rocket and its ESA Orbital Test Satellite payload on 13 September.

Circling the Earth for three years or more, the spacecraft are expected to provide detailed data on how solar wind particles control the boundaries between Earth space and interplanetary space. It is hoped this will lead to a better understanding of a variety of solar-terrestrial phenomena, including weather and climate, energy production and ozone depletion in the atmosphere.

ISEE-A, managed by NASA, and B, managed by ESA (designated ISEE-1 and ISEE-2 after orbital insertion), were the first set of spacecraft designed to be used together to investigate Earth's immediate space environment.

Shortly after third stage burnout, when the two spacecraft had attained the required trajectory, they were separated from each other but remained in the same orbit. The separation distance between ISEE-1 and ISEE-2 will be varied by the controllers between a few hundred to a few thousand kilometres during the lifetime of the mission.

For reasons of energy conservation, the smaller spacecraft, ISEE-2, weighing 158 kg (348 lb.) is the manoeuvrable spacecraft. The orbit of ISEE-1 will not be changed. Initially, however, both spacecraft will undergo attitude manoeuvres so that both point to the same place in space.

All manoeuvres will be conducted by a NASA/ESA team at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

The use of two spacecraft, separated by a variable distance, will allow scientists to study the boundaries in near-Earth space and the nature of their fluctuations. These include the plasma pause – the position at which there is a dramatic drop in the density of the magnetosphere – the magnetic envelope which surrounds the Earth; the magnetosphere,

where the magnetic field of the Earth meets that of the solar wind; the bow shock, a sort of bow wave created by the motion of the solar wind past the Earth, and several less obvious features of the Earth's magnetic tail.

Measurements by instruments on a pair of spacecraft will permit ambiguities associated with the motion of these boundaries to be resolved.

In the past, a large number of phenomena measured by single instruments on spacecraft were not clearly understood. For example, did the sudden increase in energetic particles noted from measurements by one spacecraft come from an eruption on the surface of the Sun, perhaps a solar flare, or did it come from some other source? Perhaps the particles were suddenly released from the Earth's radiation belts or were bounced back from the bow shock front that extends hundreds of thousands of kilometres out from Earth. With two spacecraft at different points on a similar trajectory with similar instrumentation, time and space aspects associated with such problems can be solved.

Even greater scientific returns will be possible when a third spacecraft, ISEE-C, is launched by NASA next summer to what is called the liberation point – about 1.5 million km (932,055 million miles) from Earth toward the Sun – where the satellite will remain with only minor onboard gas adjustments. At that point in space, the forces of gravity and the dynamic force exert an equal pull.

ISEE-C (to be called ISEE-3 in heliocentric orbit) will obtain nearly continuous data on the fluctuating solar wind, and on special solar phenomena, such as solar flares, about an hour before the solar particles flow past ISEE-1 and 2 in Earth orbit.

In certain instances, this will give scientists on the ground time to make inputs to onboard instrumentation on the mother-daughter spacecraft to look for correlating phenomena. At the same time, sounding rockets could be fired from any global location on cue from Goddard Center at different launch areas around the world to investigate other aspects of onrushing solar wind. As part of a programme called the International Magnetosphere Study (IMS), ground stations, sounding rockets, balloons, aircraft and satellites, including the ISEE spacecraft, will look at the same phenomenon simultaneously from different parts of the Earth, including polar areas and space.

ISEE coordination is designed to fit into the IMS programme, which is a world-wide three-year investigation begun in 1976. ISSE-A, B and C are major contributions to the IMS by the U.S. and Europe. Data exchange offices have been established in Meudon, France and Boulder, Colorado, USA. Meanwhile, a sophisticated Satellite Situation Center (SSC) at Goddard will calculate satellite orbits which will be published through the Boulder office. The published SSC orbits are designed for correlation with the various IMS systems to indicate when spacecraft data are likely to be especially fruitful.

Much of the data returned by ISEE is expected to be of immediate interest in areas of practical application. For example, a growing mass of evidence suggests that events on the Sun (Sun spots, solar flares, high-speed solar wind streams) may affect our weather. Long-term variations of the Sun's energy output as well as more subtle changes in the solar wind and its magnetic field structure affect our climate. Is the Earth growing warmer or colder? Will certain

[Continued on page 33

SATELLITE DIGEST - 111

A monthly listing of all known artificial satellites and spacecraft compiled by Robert D. Christy.

Continued from December issue.

Objects listed in the Digest are payloads successfully injected into orbit or a trajectory away from the Earth. They can have scientific, engineering or applications (both scientific or military) missions. The names shown are normally those given by the launching agency, international designations are allocated by the World Warning Agency on behalf of the Committee on Space Research (COSPAR). Launch dates, lifetimes and descent dates are given in days and decimals of days using Universal Time (UT). Shapes, weights and sizes are obtained from official sources, where possible. Otherwise, indirect methods are used such as analysis of orbital decay, study of photographs and comparisons with other launches. Values listed with question marks are probably accurate to within a factor of 1.5. Orbital data are provided by the Royal Aircraft Establishment, Farnborough: perigee heights are given with respect to a spherical Earth of 6378.2 km radius; the nodal period of revolution is the time between successive northbound crossings of the equator; the orbital inclination is the angle between the plane of the orbit and the plane of the equator measured at the northbound equator crossing in a direction from east through north. The launch centre and vehicles are those announced by the launching agency unless such information is not given, in which case it is inferred from orbital and/or payload data. The numbers in brackets refer to supplementary notes at the foot of each listing; information given there is obtained from NASA, Novosti, and popular or specialist press sources. The following abbreviations are frequently used: DoD – Department of Defence; ETR – Eastern Test Range. Cape Canaveral, Florida; NASA – National Aeronautics and Space Administration; USAF – United States Air Force; WTR – Western Test Range, California. The note (R) combined with a lifetime indicates that all or part of the payload has been recovered successfully on Earth.

Name, designation	Launch date, lifetime and descent date	Shape and weight weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 923 1977-59A	1977 Jul 1.50 120 years	Cylinder + paddles? 750?	2 long? 1 dia?	799	817	74.05	101.05	Plesetsk C-1 USSR/USSR (1)
Cosmos 924 1977-60A	1977 Jul 4.93 10 years	Cylinder + paddles? 900?	2 long? 1 dia?	513	550	74.02	95.28	Plesetsk C-1 USSR/USSR

Name, designation	Launch date, lifetime and descent date	Shape and weight weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 925 1977-61A	1977 Jul 7.31 60 years	Cylinder + 2 vanes? 2200?	5 long? 1.5 dia?	609	634	81.21	97.16	Plesetsk A-1 USSR/USSR
Cosmos 926 1977-62A	1977 Jul 8.73 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	976	1011	82.94	105.01	Plesetsk C-1 USSR/USSR (2)
Cosmos 927 1977-63A	1977 Jul 12.38 12.8 days (R) 1977 Jul 25.2	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	153 151	361 386	72.87 72.89	89.65 89.88	Plesetsk A-2 USSR/USSR (3)
Cosmos 928 1977-64A	1977 Jul 21.31 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	956	1011	82.96	104.69	Plesetsk C-1 USSR/USSR (4)
Himawari (GMS 1) 1977-65A	1977 Jul 14.44 indefinite	Cylinder 281	3.0 long 1.9 dia	187 35531	36744 35779	27.36 1.20	649.66 1429.43	ETR Delta Japan/NASA (5)
Cosmos 929 1977-66A	1977 Jul 17.38	Cylinder? 16000?	15 long? 3 dia?	214 312	278 318	51.59 51.58	89.36 90.78	Tyuratam-Baikonur D-1 USSR/USSR (6)
Cosmos 930 1977-67A	1977 Jul 19.36 6 years	Cylinder 2750?	9.2 long? 2.4 dia	481	514	74.02	94.59	Plesetsk C-1 USSR/USSR (7)
Cosmos 931 1977-68A	1977 Jul 20.20 12 years	Cylinder-cone + 6 panels + 2 antennae 1250?	4.2 long? 1.6 dia?	604	40065	62.96	724.12	Plesetsk A-2-e USSR/USSR (8)
Cosmos 932 1977-69A	1977 Jul 20.32 12.9 days (R) 1977 Aug 2.2	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	149 150	311 358	65.02 65.02	89.09 89.57	Tyuratam-Baikonur A-2 USSR/USSR (9)
Cosmos 933 1977-70A	1977 Jul 22.42 2 years	Cylinder	4 long? 2 dia?	384	408	65.84	92.46	Plesetsk C-1 USSR/USSR
Raduga 3 1977-71A	1977 Jul 23.89 indefinite	Cylinder + 2 paddles + 2 antennae?	5 long? 2 dia?	35730	35854	0.21	1436.3	Tyuratam-Baikonur D-1-e USSR/USSR
Cosmos 934 1977-72A	1977 Jul 27.76 12.6 days (R) 1977 Aug 9.4	Cylinder + sphere + cylinder-cone 6000?	6 long? 2.2 dia?	231 167	255 344	62.81 62.82	89.35 89.60	Plesetsk A-2 USSR/USSR (10)
Cosmos 935 1977-73A	1977 Jul 29.34 12.9 days (R) Aug 11.2	Sphere + cylinder-cone 5500?	5 long? 2.2 dia?	217	251	81.33	89.20	Plesetsk A-2 USSR/USSR

Supplementary notes:

(1) Cosmos 923 may be a military communications satellite.
(2) Cosmos 926 may be a navigation satellite.
(3) A redundant manoeuvring engine was ejected from Cosmos 927 during 1977 Jul 24; it is designated 1977-63C.
(4) Cosmos 928 may be a navigation satellite.
(5) Geostationary Meteorological Satellite launched by NASA for the Japanese.
(6) Cosmos 929 may be a development flight connected with the Soviet manned space programme. There are indications from its radio transmissions that it may be a two-part vehicle which suggests a connection with the dual launch of Cosmos 881 and 882 (1976-121A&B).
(7) This satellite represents the third Soviet C-vehicle launch during 1977 in which the satellite has remained attached to the upper stage of the launch vehicle. See also 1977-11A and 1977-31A.
(8) Cosmos 931 may be a military early warning satellite.
(9) A redundant manoeuvring engine was ejected from Cosmos 932 during 1977 Aug 1; it is designated 1977-69D.
(10) A redundant manoeuvring engine was ejected from Cosmos 934 during 1977 Aug 8; it is designated 1977-72D.

Amendments and decays:

1965-108B, LES 4 may have decayed 1977 Aug 1, lifetime 4241 days.
1965-108C, Oscar 4 may have decayed 1977 Apr 12, lifetime 3765 days.
1976-04A, CTS 1 is a cylinder + 2 wings, 1.88 m long and 1.83 m dia, with a span of 16.8 m, it's weight is 680 kg fuelled.
1976-23A&B, LES 8 and LES 9 are shaped as a cylinder + box, 3.0 long and 1.6 m dia.
1976-42A and 1976-73A, Comstars 1A and 1B weigh 793 empty.
1976-57A, Salyut 5 was de-orbited 1977 Aug 8, lifetime 412 days. During this time, it completed 6630 orbits and supported two crews of cosmonauts for a total of 64 days.
1976-63A, Cosmos 838 disintegrated during the period late June-early July, 1977. The main fragment decayed 1977 Aug 23, lifetime 417 days.
1976-66A, Palapa 1 weighs 782 kg empty. fuelled

ARTHUR VALENTINE CLEAVER, OBE

(19)

Val Cleaver was the United Kingdom's closest equivalent to his good friend Werhner von Braun, who predeceased him by exactly three months. He was his country's undisputed leader in the field of rocket engineering, and his professional career spanned the rise and fall of the British rocket industry. There can be little doubt that his untimely death was due in no small measure to that national failure, and to the heartbreak of seeing the dispersal of the brilliant and enthusiastic teams he had recruited, trained and encouraged.

For over forty years, Val Cleaver was in the forefront of the British space movement, and as an officer and Chairman of the BIS he devoted most of his spare time to the Society. His practical experience and shrewd common sense were beyond price, often helping to correct the wilder fantasies of less inhibited space enthusiasts (such as this writer).

A full account of Val Cleaver's technical achievements – both theoretical and practical – is beyond the scope of this brief appreciation. But mention must be made of the pioneering series of papers, *The Atomic Rocket*, which he and Dr. Shepherd published in the BIS *Journal* (1948-9). And he led the team which developed the engines for the Blue Streak and Europa first stage engines which never failed in any of the test flights.

During his last few years, failing health and a baffling eye complaint which made reading very difficult greatly reduced Val's activity. But he was never failing in his helpfulness to his many friends, especially those at the beginning of their careers.

It is unlikely that Val Cleaver had any real enemies, though the occupants of various ministries had good reason to be scared of him. One of my keenest regrets – in addition to that caused by losing an old and dear friend – is that he never had a chance to produce the exposé of British (and European!) aerospace politics that he was uniquely qualified to write.

It will take a long time to realise that he is really gone, and that there is now no further point in collecting books and news items to send on to him.

ARTHUR C. CLARKE
Colombo, 18 September 1977

A. V. 'Val' Cleaver (14 February 1917- 16 September 1977), Honorary Fellow, British Interplanetary Society.

Val Cleaver's professional life can be divided into three periods – the propeller period, the rocket period and the remainder. The propeller period began in 1935, when at the tender age of 18, he joined de Havilland's and very quickly assumed a dominant role during that difficult period when the variable pitch propeller was being introduced into this country. This period covered the war years when vast numbers of propellers were being delivered for the R.A.F. My memories of Val during these range from his insistance on absolute professional integrity, which he took very seriously, to drilling sessions with the LDV, which he didn't!

In 1946, he relinquished his propeller activities to join Major Halford, who invited him to spend a year just "looking into rocket engines." Val often claimed that this was one of the happiest times in his life – no dates to be met or

A. V. Cleaver (right) chats with Dr. I. M. Levitt during the London IAF Congress, 1959.

programmes to be achieved – just reading and talking and understanding one of his greatest interests.

This sabbatical period led to the formation of the de Havilland Rocket Division which he led for nearly ten years. During this period, Val became rather more of an elder statesman, looking after important visitors and potential customers, influential Ministry officials and not always sympathetic directors. This did not prevent him taking a keen and decisive role in day-to-day events. For example, when the first of our rocket engines (the Sprite) was run for the first time, he decided he wanted to press the button himself, insisting, half jokingly and half seriously, that we should not both be there, in case it blew up!

Val's rocket engines activities continued at Rolls-Royce where he took on the even greater task of developing the RZ2 engine for "Blue Streak," inheriting and building up a new team in the process. Eventually, he found himself responsible for all the liquid propellent rocket work being carried out industrially in the U.K.although by this time, the writing was on the wall, and cancellations were far too customary.

Val's professional life was a mixture of success and frustration. He always hoped, but never really expected, that the U.K. would play a significant role in rocket propulsion and space. This was not to be realised, and during the last few years of his working life, he was not professionally involved with either of his life-long interests.

Nevertheless, by his personal contacts, writings and lectures, he played a very significant part, on both sides of the Atlantic. Generous to a fault, he could always be relied upon for good advice and counsel, especially if you were young and aspiring. He will be sadly missed by many friends everywhere.

W. N. NEAT

It was with the deepest regret that we learned of the death of our friend Val Cleaver.

We remember him to be one of the small group of real space enthusiasts in Europe promoting space flight long before the launch of the first satellite.

He devoted his work later to the ELDO activities of the European launcher development (Blue Streak and H_2/O_2 Propulsion) and promoted heavily a greater UK activity in the space field over the past decade.

He was an honorary member of the German Society for Aeronautics and Astronautics (DGLR) and received the 4th Hermann Oberth Medal for his merits and contributions to European space activities in 1953.

We always will remember Val as an outstanding character and a personality very rare during these times.

LUDWIG BÖLKOW,
ROLF ENGEL,
DIETRICH E. KOELLE,
Munich, West Germany.

Proposed A. V. Cleaver Memorial

Val Cleaver's many friends around the world may like to know that a proposal has been made that a Memorial to his work be incorporated in the Society's new offices and a suggestion advanced that the amount collected be used e.g. to purchase an **illuminated exhibit display case.**

The Society's Council commends this and has authorised the setting up of a fund for this purpose. Those wishing to contribute Donations should send them to: Mr. L. J. Carter, Executive Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, SW1V 2JJ.

To me personally it was a tragic loss of a very close friend and one who had more influence on the course of my life than any other. I first met Val in 1962 at which time I was the subject of one of his particular interests,namely the encouragement of young people who had shown innovation. I was a 17 year old youth who had been engaged in amateur rocket activities, news of which reached Val's ears. He responded in a way which I now know to have been typical of him, by inviting me to visit the Rocket Department at Rolls-Royce and spending an entire afternoon and evening discussing numerous aspects of space flight and rocket engineering, including some sound advice on my own activities. Following this first meeting, some years elapsed whilst I obtained a degree and an apprenticeship, before I eventually joined Val's rocket group at Rolls-Royce, Derby and later at Coventry.

Working in the rocket department for Val was always more than just a job for the people employed there. There was a sense of involvement which the (now ex-) rocket department members recall with regret at its loss. This sense had its roots partly in the nature of the product, but also from Val himself who ran the team more like a family rather than through an impersonal management structure. Indeed, although a batchelor himself, he had a very good understanding of people and their personal involvements.

Of course, the main characteristic which everyone will recall of Val was his unfailing common sense and his ability to direct enthusiasm along useful lines without stifling it. He was however very critical of experienced people who made proposals of a naive nature and in particular those proposals which neglected the effects of politics or used grossly enormous costs or timescales. Many current proposals for future developments in space came in for this sort of criticism.

Val's contributions to space flight in a direct sense are difficult to assess. His encouragement to many people all over the world has been acknowledged as a contribution in its own right. His material achievements would undoubtedly have been greater had it not been for the meanderings of political objectives in Britain and the failure of vision of certain Ministers responsible for technology. Despite these obstacles, however, he was responsible for the development of many rocket engines which were successful, but in particular his group at De Haviland's developed the first topping-cycle engine in the Spectre, a cycle which pioneered those now used in advanced engines in the USA and USSR. Together with Dr. L. R. Shepherd he carried out pioneering theoretical work on the solid core nuclear rocket, a version of which was successfully developed (but later abandoned) in America and more recently he proposed the dual-fuel engine cycle as a natural engine for mixed-mode vehicles, a concept in which he had considerable interest. The eventual impact of this later contribution remains to be seen.

ALAN BOND

I was shocked to learn of Val Cleaver's death. His incisive mind, earnest personality, and tireless dedication made him one of the great figures in the world of rocketry and astronautics.

F. I. ORDWAY

Please accept the enclosed donation (cheque for £10.50) on behalf of Blue Streak Rockets – Derby and Ansty – as a contribution towards the Val Cleaver Memorial at the British Interplanetary Society.

K. R. SAMWAYS
Applications Department,
Rolls-Royce Ltd.

BIS EDUCATIONAL SUPPLEMENT

A Publication of The British Interplanetary Society,
12, Bessborough Gardens, London, SW1V 2JJ.

BRITAIN FROM SPACE

Commentary by D. J. Carter B. A., Senior Lecturer in Geography,
Portsmouth Polytechnic, and H. J. P. Arnold, M.A. (Oxon)., FBIS.

UNTIL THE LAST FEW YEARS the United Kingdom and most of Europe did not appear in photographs of the Earth taken by American astronauts since the orbits of the Mercury, Gemini and Apollo spacecraft were not far enough to the north of the Equator. The first, albeit crude images came in the 1960's from weather satellites whose primary purpose was to secure information about weather phenomena rather than the land surface below.

However, in July 1972 the United States National Aeronautics and Space Administration launched its first experimental satellite devoted to what is termed the 'remote sensing' of Earth resources – and Landsat was placed in an orbit which took it over most of the Earth's surface including Europe. A second Landsat was launched in 1975 and two other spacecraft in the series are scheduled for launch in 1978, and 1981. The Skylab space station which was occupied by three crews of astronauts in 1973/74 came as far north as 50° from the Equator which enabled oblique photographs of the UK to be taken. The pictures presented in these pages have been selected mainly from Landsat pictures, with the addition of one Skylab and one weather satellite view.

Pictures courtesy of NASA/US Geological Survey, USAF Weather Service, General Electric Company and Donald S. Ross.

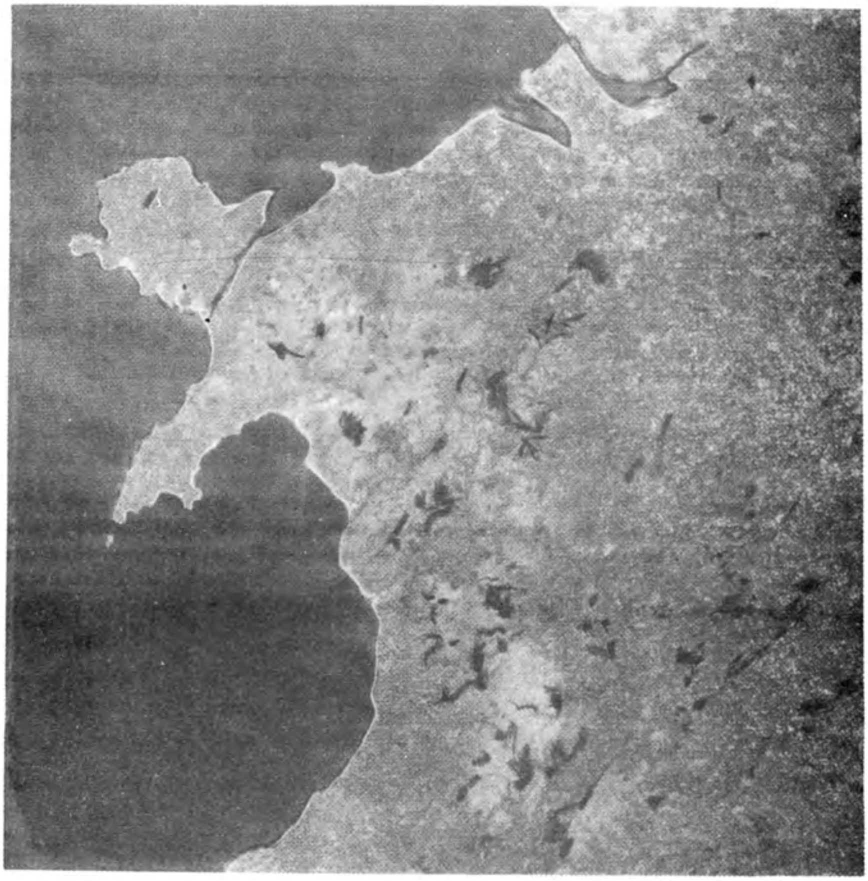
THE UK IN SUMMER

This picture was obtained by a US Air Force Defence Meteorological Satellite on 29 June 1976 at 6.41 am GMT. The instrument employed was a scanning radiometer incorporating a Cassegrain optical system yielding a ground resolution of somewhat over 2 miles.

The clouds in the image graphically depict the synoptic situation at the time. A cold front lying NE/SW is moving slowly in a south-easterly direction close to NW Scotland. Close to Norway, however, this front is moving more quickly south and east and is catching up with and occluding a warm front over southern Norway. The associated depression lies to the north of Iceland. To the west of Britain, the trough of low pressure is already swinging back slowly northwards as a warm front.

A high pressure area is centred over the North Sea – with a ridge of high pressure extending eastwards over northern Europe and westwards into the Atlantic. (Another high pressure area is centred to the west of the warm front over mid-Atlantic). Of particular interest are the wave clouds produced by the south-westerly winds blowing over the comparatively shallow topographical features of northern Scotland, the Western Isles, the Faeroes and southern Iceland.

This Special Educational Supplement has been bound into the centre of the January 1978 issue of 'Spaceflight' as an aid to teachers and others who wish to explain the practical benefits of space technology to a wider audience. The double pages can be detached for display on notice boards.



NORTH AND CENTRAL WALES

A supremely clear false colour composite of north and central Wales; the Merseyside conurbation; the Welsh borderland and a part of the western and northwestern English Midlands. It was imaged on 8 June 1975.

The dark tone of the sea provides an admirable background against which to appreciate the fretted outline of the coastlines of the Lleyn peninsula and Anglesey. This contrasts with the smooth, arcuate form of Cardigan Bay. The 'Z' form pattern of the bays around Lleyn is as apparent as the drowned but shallow estuaries of the Welsh coast such as the Dovey, while the 'bottle'-shaped estuaries of the Dee and Mersey add further to the variety of coastal morphology that can be seen.

The extensive plateaux of the Welsh upland, deeply incised into by relatively widely-spaced glaciated valleys, are represented by considerable tonal variety. Some of the lighter tones are related to areas of high altitude where outcropping rock surfaces, discontinuous and thin soils, and relatively simple associations of moorland vegetation species combine (e.g. in the Plynlimon and Snowdonia areas). The much darker tones of areas of upland coniferous tree plantation are very evident. The linear pattern of the major lakes (almost black in colour) indicates their confinement within wide, but deeply-dissected valleys. Lake Vyrnwy is a reservoir for storage of public water supplies for the Midlands.

SOUTH WALES, THE SEVERN ESTUARY AND COTSWOLDS

This image affords a clear view of the structural and relief patterns of the southeastern Welsh massif; the southern Welsh borderland; the lower Severn valley and estuary (the Bristol Channel); the southern Cotswolds; the mosaic of hills, valleys and lowlands of the Bristol region; and the upland of central and northern Devon. The Somerset lowland between the Quantocks and Mendip is readily discerned, whilst towards the right edge of the frame the chalk country of Dorset and parts of Wiltshire is also visible.

The details of relief texture are accentuated by the low angle Sun elevation. Steep and long slopes facing north and north-west are in shadow and produce the strong linear features that make the most immediate visual impression. In several places there is either discontinuity or detailed irregularity affecting the major lineations. An example of the former is seen in central Wales, where hill ridges, aligned NE-SW, fade out and then re-assert this pattern, traceable over considerable distances. The latter is represented by the embayed form of the primary Chalk scarp (facing west) and by the numerous re-entrants into the Cotswold scarp. The narrow sub-parallel ridges of western Mendip, where relief inversion has occured, exemplify a more nearly west-east orientation which is easily linked with the similar alignment of the lowland embayment of the Vale of Pewsey to the east.

WALES, THE SOUTHERN PENNINES AND THE ENGLISH MIDLANDS

A portion of a full frame which yields precise definition of relief contrasts of a part of Wales; the Welsh Borderland country; the southern Pennines and the western and central English Midlands. This is a product of low solar illumination angle (the image was obtained on 14 February 1976) throwing north and north-west orientated slopes into deep shadow. Many of the flat-floored and steep-sided glacial valleys in the Welsh uplands are very clearly discerned, but it is the linear form of some of the smaller scale land-forms that makes the more immediate impact. Especially clear are the sub-parallel hill masses of south Shropshire alternating with strike and fault vales. The Long Mynd, the Church Stretton rift and Wenlock Edge are especially well-defined. The Vale of Clwyd in north Wales, another in-faulted structure, is also well delineated.

Over industrial urban areas such as Birmingham and Merseyside smoke emission plumes are prominent. Note that those in the first area all "tail off" in a south-western direction, whilst those in the latter area do so towards the north-west. The area of smoke diffusion over Merseyside is considerable.

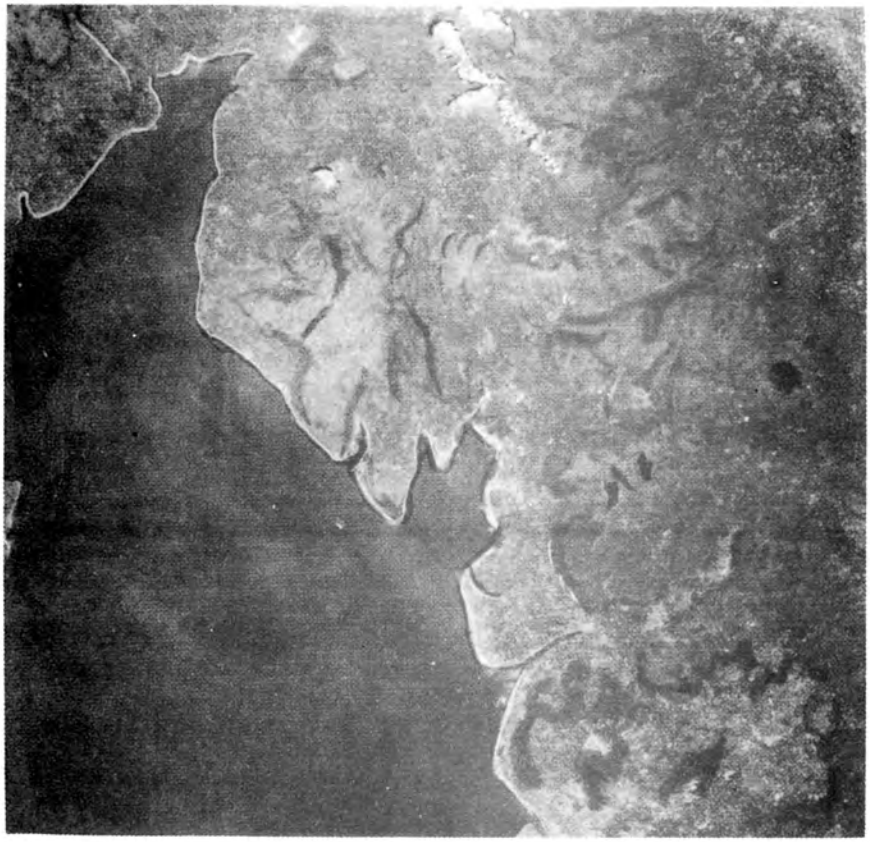
SOME NATURAL RESOURCES WE CAN MONITOR FROM SPACE

WATER

OCEAN

AGRICULTURE

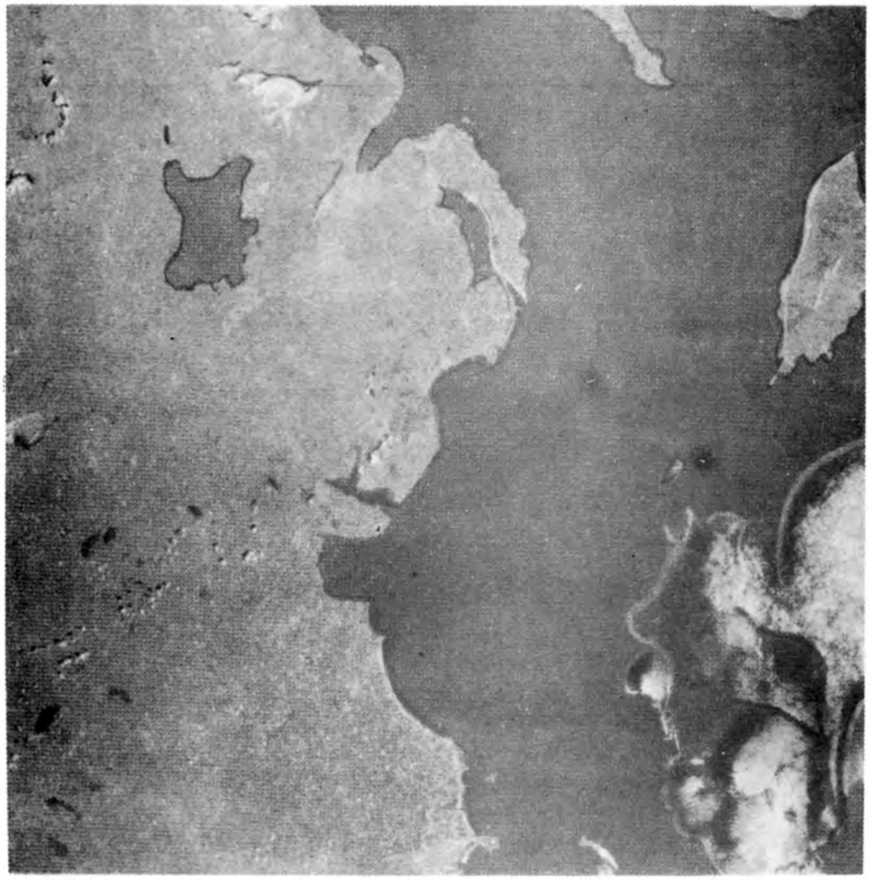
MINERALS AND OIL



NORTH-WEST ENGLAND

The distribution and identity of areas of inland water is a striking feature of this image of North-West England obtained on 8 June 1975. The roughly radiating pattern of the glacially overdeepened troughs that accommodate the lakes of the Lake District contrast with the small 'pinheads' of dark tone that represent upland tarns. Small to medium-sized lakes are numerous within the valleys and dales of the Pennine and Rossendale Forest uplands; they are also numerous within the Greater Manchester conurbation. Many of these water areas are natural or man-made reservoirs, and they are a token of the importance of water as an industrial resource in this area.

The form of the major conurbations is very clearly discerned in this image, which preserves the identity of the old cotton towns of south Lancashire and gives a strong impression of the 'constellation' form of the Greater Manchester urban area. Spectral signatures from improved and unimproved grassland are also readily distinguished. The saturated red of the re-entrants of lowland agricultural land use along the Yorkshire Dales (predominantly permanent grassland) contrasts effectively with the brown of the large intervening blocks of upland moorland vegetation. Teesdale, Swaledale and Wensleydale are especially clear in this respect.



EASTERN IRELAND AND THE ISLE OF MAN

A largely cloud free image of a large part of eastern Ireland, extending across the Irish Sea to the Isle of Man, taken on 10 June 1975. The approximately north to south orientation of the Irish coastline, as well as the large inland lake of Lough Neagh, is an expression of structural control. Dark tones show up the large number of small bodies of standing water, some of which are clustered together and show patterns of alignment. These result from impeded drainage on the mantle of glacial drifts and more recent peats that occupy large areas throughout the Irish lowland. The numerous small lakes at lower centre left of the image frame are related to 'swarms' of low drumlinoid hills (formed beneath the ice and made up of glacial drift). The channels of some of the major rivers are readily discriminated against the red background – for example, the Boyne. Almost ubiquitous grassland accounts for the uniformity of colour, the only variety being offered by the dull brown of upland areas such as the Mourne Mountains. Because of the uniform representation of rural land use, major settlements are effectively delineated. The radiating urban form of Belfast is clear, but smaller towns, such as Armagh, Ballymena, and Lisburn can also be readily identified.

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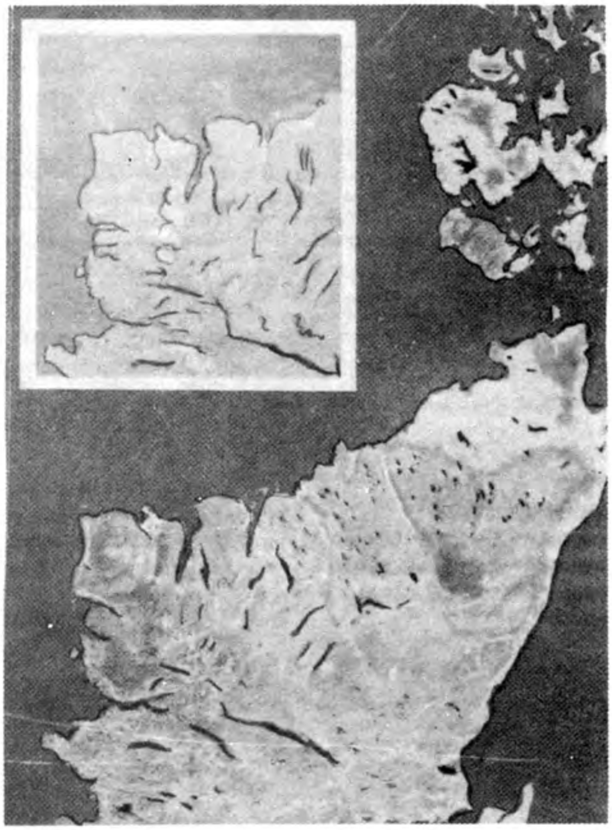
12, Bessborough Gardens, London, SW1V 2JJ.

NORTHERN SCOTLAND AND THE ORKNEYS

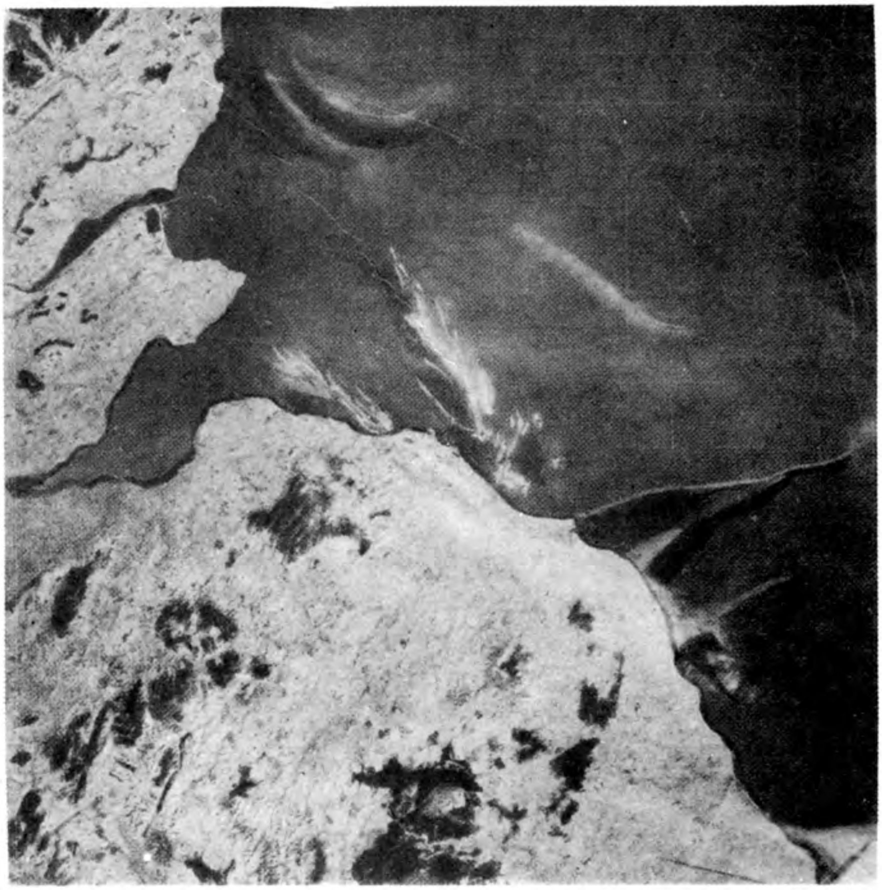


The near infrared bands imaged by the Landsats can penetrate haze and thin clouds. This is demonstrated by the main image in this frame – which is part of the scene imaged on 4 August 1975 in the 0.7-0.8 micrometers waveband – when compared with (inset) a portion of the same view imaged at the same time in the 0.6-0.7 micrometers (visible red) waveband. This underlines the value of the different wavebands to different disciplines – the visible bands, for example, facilitating atmospheric and meteorological studies (note the wave clouds in the top, right corner of the inset image) with the near infrared bands facilitating study of land mass topography and land/water differentiation.

The main image conveys a clear distinction of landscape contrasts. Light tones are associated with more intensive land use located on areas of limited local relief, as in Caithness; around Dornoch Firth; along parts of the coastal zone; within the major valleys; and over much of the Orkney Islands. A variety of grey tones relate to extensive land use of upland rough grazing. The more complex textural and tonal patterns of the higher relief areas of North-West Scotland show up well, though the inset image reveals the higher summits more effectively. The black tone of water surfaces on the main image locates with accuracy the numerous small lake bodies, quite apart from the major inland and sea lochs. The various sets of alignment directions affecting the lochs – products of glacial overdeepening of pre-glacial valleys – is very apparent on both images. The role of tectonic structures within this geologically ancient and very complex area in guiding the development of the landscape is strongly implied. The comparative tonal and textural simplicity of the extreme north-east of Scotland corresponds with its lack of geological complexity.

A number of the original photographs included in this review are in colour which explains the references to colour in the individual captions.

NORTH-EAST SCOTLAND



This is part of a larger, false colour composite frame, and incorporates the eastern part of the Scottish uplands; the Cheviots, a small portion of the lowland of North-East England; and part of the Fife peninsula. It was taken on 11 March 1973.

Whilst permanent grass is a reddish pink tone, as seen especially well in the areas intermediate between upland and lowland, land use associated with immature arable crops, fallow land and small woodlands is turquoise green. The higher incidence of this latter type of land use along the coastal margins and within the Tyne and Tweed Valleys helps to differentiate the main land use regions of the whole area. The dark-reddish browns in upland areas record the pattern of coniferous plantations. Within the Kielder forest of Cheviot, forest tracks and some firebreaks can be discerned. The channels of the major rivers can be distinguished with particular clarity – notably the River Tweed and its major tributaries – while the shadow of the north and north-west facing slopes helps to characterise the detail of dissection of the upland relief.

The dominant NE-SW trend of the major tectonic structures is well exemplified by the coastline of the Firth of Forth. The overall pattern of afforestation blocks confirms this regional trend, and it is further reinforced by the valley of the Tweed.

No satellite has stirred more excitement than Landsat. The late Dr. Wernher von Braun predicted that through this one programme alone, the United States could realise "a return exceeding its total space programme investment." Apart from Landsat's considerable potential for agriculture, the imagery has already led geologists on oil and mineral hunts in Alaska, Oklahoma, the Rocky Mountains and the jungles of Brazil. Biologists have been able to detect potential fishing grounds. Changes in ecology brought on by forest fires, earthquakes and strip mining have been plotted. Landsat data has also provided the raw data to indentify the polluters of air and water. To date the oil and mining industries are the largest purchasers of Landsat data, which are made available through the US Department of the Interior's EROS Data Center at Sioux Falls, South Dakota. *Pictures and text of this Special Educational Supplement have been adapted from a series of slides produced by Space Frontiers Limited, 30 Fifth Avenue, Havant, Hampshire, England.*

SOUTHERN ENGLAND AND THE ISLE OF WIGHT (left)

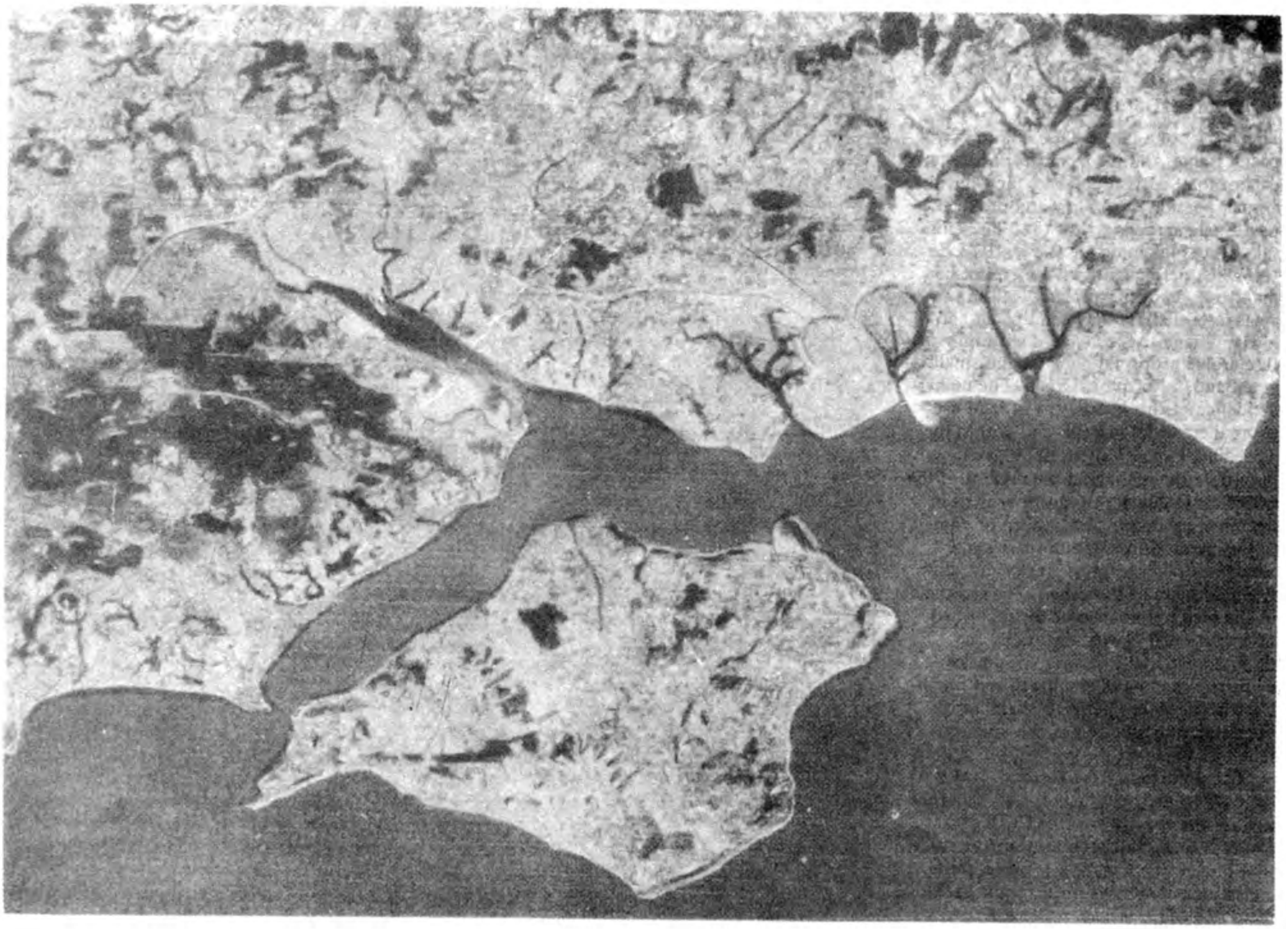
This image is an enlargement of a relatively small area from the 0.6-0.7 micrometers band of another photo. The purpose is to establish the degree of detail discernible. There is no point in enlarging a Landsat frame beyond the resolution of the scanner system in the hope of seeing more detail, while at extreme enlargements the horizontal scan lines begin to intrude more and more. In addition, the photographic stages between the receipt of telemetry from the spacecraft and the production of the final image form a potential, variable limitation on the resolution of any image.

The scale of a full-frame Landsat image is 1:1000000 i.e. one inch on the image equals one million inches on the ground. That is a very small scale. In the original of this enlargement, the effective scale has been increased to 1:190,000.

The delimitation and recognition of both natural and man-made targets is facilitated where there is physical adjacency of objects returning contrasting spectral signatures. This is well seen in the southern New Forest where areas of woodland (dark tones) contrast well with areas of heathland and improved grass (medium grey) that exist both within and marginal to the former areas. The distribution of woodland on the backslope of the South Downs and in the Isle of Wight is clearly recognised; indeed, an orthophoto map of woodland cover over the whole area could be undertaken with very reasonable accuracy. Within the South Downs, woodland partly coincides with the strong dark coloured lineaments that extend NE-SW and NW-SE. These are well-developed scarp slopes that define a series of 'prow'-shaped hills about 2 km south of the primary scarp. This north facing slope pattern is accounted for by the fact that it was in shadow at the time of imaging.

Subtle features are apparent if the areas of heathland and woodland are scrutinised: forest tracks and firebreaks can be differentiated from the surrounding vegetation and immediately north of Lymington the pattern of runways of a disused airfield can be seen. On the wide flood plains of the Itchen and Test valleys, the dark grey of the permanent pastures contrasts with the light tones of growing crops on the adjacent divides.

Light, almost white areas, distinguish numerous man-made features. The line of the M27 motorway between Portsmouth and Southampton, and again north and west of Southampton, catches the eye. The runway of Eastleigh Airport; reclaimed land in the north-eastern part of Portsmouth Harbour; Southampton waterfront and Marchwood on the western side of Southampton Water; and Fawley oil refinery are amongst various other features that can be discerned due to bright tonal characteristics.



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12, Bessborough Gardens, London, SW1V 2JJ.

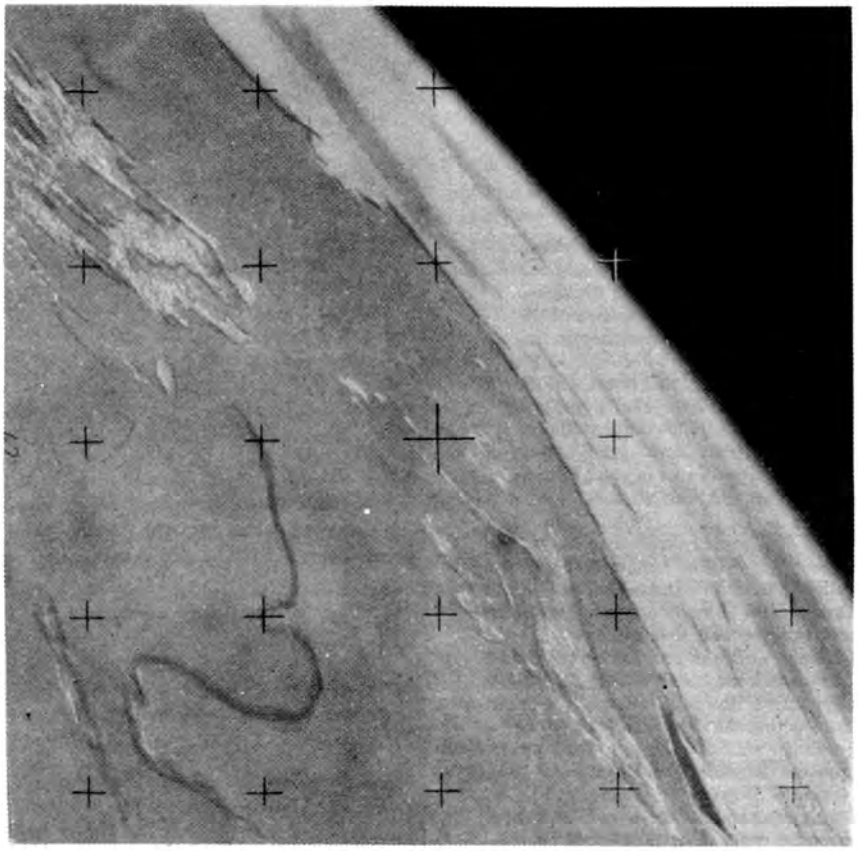
SOUTH-EAST ENGLAND (top & bottom)

Part of two false-colour composite frames of south-east England: the one at the top was imaged on 29 July 1975, the one below on 11 February 1976. Within the area of coverage common to both, spectral variation is caused by (i) seasonal changes affecting vegetation and field crops and (ii) changes in the angle of solar illumination.

Low Sun angle enhances the primary relief pattern of the eastern Weald and the chalk downs of Kent on the right-hand frame while the definition of the well-incised dry valley network on the backslope of the chalk in east-Kent is also accentuated by this effect. On the bottom frame relative relief is less easily appreciated but some compensation is offered by the distinctive spectral tone of the chalk outcrop area of the Chilterns and the East Anglican heights.

The top image has resolution detail that is of a higher quality than for any other single, original Landsat image of the British Isles so far examined. The ribbon development of many of the major urban centres is precisely delineated – for example, along the Lea Valley, north of London and the line of the A12 towards Chelmsford. Homogeneous areas of open space within the urban fabric of Greater London – such as Richmond Park – are apparent. Singular features such as Heathrow Airport; the reservoirs of the Staines-Walton-on-Thames area; and the extensive chalk quarries of lower Thameside are clearly pin-pointed. The bottom frame does not offer the same clarity and consistency of resolution but discernment of detail is possible where lighting conditions emphasise quite subtle and small-scale landscape variation – for instance, the successive shingle ridges of the cuspate foreland of Dungeness.

The colour and tonal variations that record rural land use on the two frames are not mutually compatible, owing to the fact that one is a summer scene, the other a winter scene. On the top (summer) frame, the background red signal can be differentiated into several distinct tones that record separate cover types – e.g. standard 'pink' for mature grassland; brick red for deciduous woodland (a good example is Epping Forest); and brown tones for both coniferous trees and heathland, as in the case of Breckland. The distinct spectral character of chalkland is emphasised. On the bottom (winter) frame, dark pink tones again differentiate grasslands, but woodland and heathland register as a variety of tones and colours. This could be accounted for partly by variations in soil humidity but is fundamentally the result of the dormancy of vegetation and the lack of field crops. Cloud shadows may introduce some additional tonal variety and are a source of interpretational ambiguity.



THE UNITED KINGDOM FROM SKYLAB

This image was exposed at 1400 GMT on 13 September 1973 during the Skylab 3 mission. There are obvious differences from the Landsat frames. In the first place – while over other regions of the world Skylab Earth resources experiments were conducted in which the photographic cameras and other instruments were pointed directly below the spacecraft as is the case with Landsats – the space station never orbited far enough north to come over the UK. Therefore the astronauts had to take pictures with hand-held cameras pointed obliquely towards the north. This inevitably resulted in more distortion in the images than in Landsat or regular Skylab Earth resources experiments – and also in a greater risk of loss of detail since the surface was not being viewed through the shortest depth of the atmosphere (directly below) but to one side. Nonetheless, because of the smaller scale the picture gives a more immediately recognisable regional overview than is possible with Landsat images.

The second major difference is the preponderantly blue colour of the picture It was exposed on conventional photographic colour film which 'sees' broadly the same colours as the human eye does from orbit. This overall colour balance is caused by the atmosphere scattering the shorter (blue) wavelengths of light much more than the longer wavelengths. The use of infrared instruments or film largely overcomes this particular problem but the resulting images are not suitable for some investigators.

Much of Wales, central, northern and eastern England, Scotland and part of Ireland are shown. An area of high pressure is centred about 100 miles to the north-east of Aberdeen, with a ridge of high pressure extending westwards over northern Scotland and into the Atlantic and east-south-east over the North Sea and Denmark into Europe. A deepening depression over northern Scandinavia is moving quickly south-eastwards. The great mass of cloud over the North Sea and Scandinavia in this frame is low level stratus and stratocumulus. Over the British Isles, there are individual or small patches of cumulus type cloud showing white while there are far more extensive areas of grey – comprised probably of very thin, low cloud beneath which, in the high pressure conditions, dust and smoke have been trapped to give rise to hazy conditions.

At the Earth's limb the comparatively thin, effective envelope of the atmosphere is recorded as a clearly discernible light blue band caused by atmospheric scattering of light.

THE VALUE OF REMOTE SENSING TO BRITAIN

Over the past decade the value of spacecraft in providing information about the land, oceans, rivers and atmosphere of the Earth so that we may manage these resources with greater awareness and knowledge has been extensively studied. The principal assets of the spacecraft are the great expanse of the Earth's surface recorded in just one view and its ability to repeat such views – the frequency depending on the characteristics of its orbit. The studies have demonstrated many potential uses and others which are being applied already practically – like geological analyses which could well play a major role in locating new mineral and other resources, the small scale mapping of remote or inaccessible areas of the world and ice surveillance in the far north of Canada.

The value of remote sensing from space to the UK and other countries of Europe, however, still remains to be proven. Cloud covers the area more frequently than in many parts of the world and this – together with industrial haze – greatly reduces the information which spacecraft instruments can gather. The UK is already a well-mapped country (although maps quickly become out of date) and the detail distinguishable from spacecraft will almost certainly have to be improved greatly before a comprehensive contribution to our maps or detailed surveys of land usage for example can be expected. But it would be most unwise to dismiss the potential of the Earth resources spacecraft to the UK. Already one English university group has shown that charts classifying sand banks, mud flats, clear water, sediment laden water and so on in coastal waters can be made much more quickly using Landsat data than by conventional methods. In addition, the Department of the Environment has been studying the value in urban land use mapping of Landsat images enhanced by computer techniques. The technological capability and versatility of the remote sensing spacecraft seem certain to improve in the future and the European Space Agency is studying the application of instruments which will be less susceptible to weather conditions. The remote sensing of Earth resources will be among the major studies to be conducted aboard the manned Space Shuttle when orbital flights begin in 1979.

The pictures included in this set thus represent a promise of future, practical, even routine applications which have still to be elaborated in this country. They have an importance for that reason alone. But even at this time they also have value in showing our country as it really is – or, rather, as represented by the sophisticated instruments aboard spacecraft – thereby breathing an element of reality into the representation in atlas or map.

EVOLUTION OF THE SPACE SHUTTLE

By David Baker

6. FREE FLIGHT TESTS BEGIN

Continued from the issue of June 1977, page 217]

Test Objectives

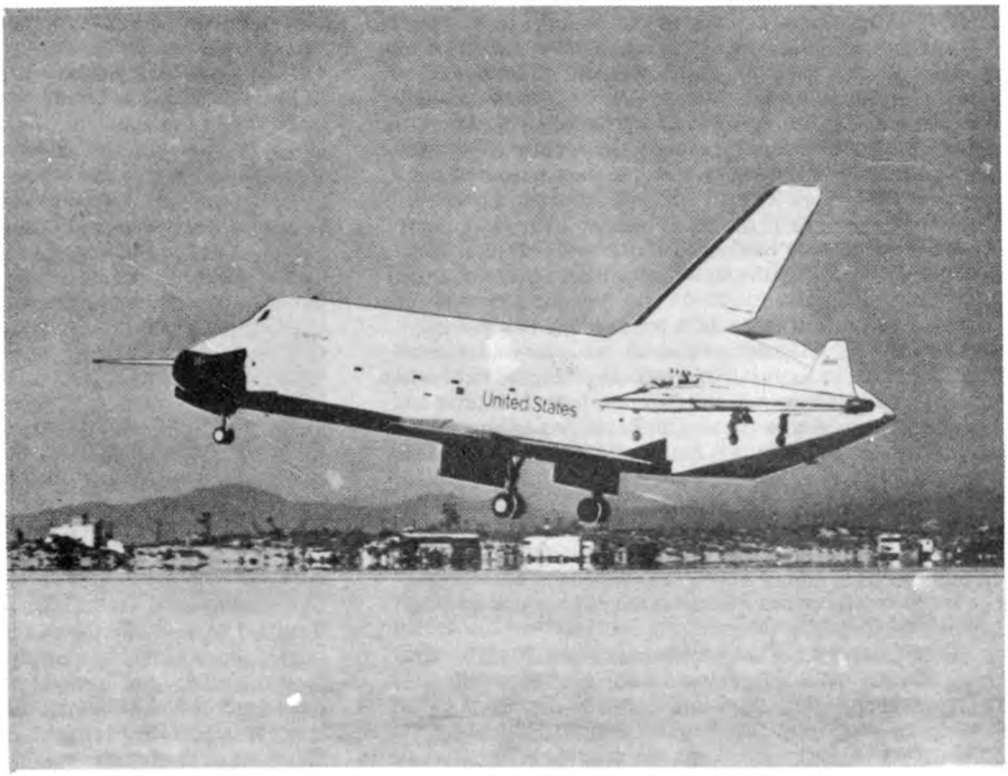
After five years of concerted effort at several NASA centres, prime contractor facilities in California and a myriad subcontractor plants across the United States the Shuttle is finally leaving the nest and flexing its capable muscles. A description of the Approach and Landing Test (ALT) programme appeared in *Spaceflight,* Vol. 19, No. 6, on pp. 213-217 where the pre-test schedule can be found along with a summary description of the hardware and flight objectives. Broadly, the latter embraces:

1. Qualifying the Orbiter/Shuttle Carrier Aircraft (Boeing 747) configuration (it will have a continuing role as prime carrier for delivering Orbiters from the production line to the launch site and of returning Orbiters to the launch site when they return from space to a landing remote from the Kennedy Space Center or the Vandenberg Air Force Base);
2. Providing an opportunity for testing aerodynamic control surfaces and undercarriage deployment without the risks accompanying independent flight;
3. Qualifying Orbiter electrical, hydraulic and cooling subsystems while still attached to the Boeing 747;
4. Familiarising the crew with flight deck functions in an operational setting;
5. Providing operating experience with handling the Orbiter in independant flight;
6. Generating aerodynamic handling and performance data preparatory to the first orbital missions;
7. Setting up an active ground-to-air monitoring loop for personnel in control room situations preparatory to space operations.

Mating the Orbiter

Following completion at the Palmdale assembly facility Orbiter 101 was moved by trailer to the Hugh L. Dryden Flight Research Centre adjacent to Edwards AFB in California on 31 January, a distance of 58 km along existing roads specially widened for the journey. To place the Orbiter on top of the SCA (Shuttle Carrier Aircraft) OV-101 was first moved into the special Mate-Demate Device (MDD) consisting of an open steel work structure with three 45.4 tonne capacity hoists for lifting the space vehicle off the ground. Two hoists were attached to the rear of the Orbiter and one to the forward section. The MDD consists of two steel towers 30 m tall with a horizontal cantilever structure 24 m above ground level and 21 m long. When the Orbiter is in position for attachment to the hoists the nose is between the two towers and the fuselage is directly beneath, and in line with, the cantilevered section. Seen from above the MDD forms a letter T, with the two towers forming the horizontal bar and the cantilevered structure setting the vertical axis. When the Orbiter is raised a few metres off the ground the undercarriage is retracted and the SCA (Boeing 747) is moved in underneath. The Orbiter is then slowly lowered on to the top of the fuselage and mated to the three attachment struts. The MDD will be used throughout the Shuttle programme for placing, or removing, Orbiters on to, or from, the top of the SCA and similar structures will be set up at the Kennedy Space Center and the Vandenberg AFB. Initial Orbiter 101/SCA mating came on 8 February 1977.

After ground vibration tests with the dual configuration the assembly was ready for the Approach and Landing Test programme to begin but first the general handling characteristics were evaluated in a series of three high speed runs along the runway. These were performed on 15 February, using runway 04/22. Adopting runway 22 for the first of



Space Shuttle 'Enterprise' nears its point of touchdown on Rogers Dry Lake in the Mojave Desert on 12 August 1977 to complete the first free flight of the spacecraft during the Approach and Landing test phase. Concealed near the boattail, in this picture, is a T-38 chase plane monitoring the landing.

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these the assembly reached a speed of 76kt (knots) moving north-east before slowing down to 23 kt and applying the wheel brakes. Inspection of the Boeing's wheel assemblies showed no damage or overheating and the second run used way 04 for a roll to 120 kt during which, at a speed of 95 kt, SCA pilot Fitzhugh L. Fulton raised the nosewheel to test elevator effectiveness. The third taxi test involved rotating the SCA nose 5° and a maximum speed of 137 kt; the Orbiter/SCA assembly would become airborne at a nose pitch of 6.5° and a speed of 145 kt. This final run incorporated braking tests between 49 kt and 40 kt; the preceding run had put brakes on at 20 kt.

ALT Programme, Phase 1

The final taxi test was a complete success and the programme moved quickly to Phase 1 of the ALT programme. This was envisaged as a series of six captive-inert flights during which the unmanned Orbiter would be carried on top of the Boeing 747 without crew or systems activation in evaluation of the flying and handling characteristics of the mated configuration. At this time the six flights were scheduled for 18, 22 and 25 February and 1, 4 and 8 March. Phase 2, the captive-active tests, would then begin on 26 May and in a series of five flights the Orbiter would remain mated to the SCA but with a two-man crew on the flight deck perform checks on Orbiter subsystems, test aerodynamic control surfaces and provide pilot familiarisation with in-flight operating techniques. Phase 3, the free-flight series, would begin during the fourth week of July and embrace five descent flights to landings at the Dryden Flight Research Center.

Following these a single captive-active flight would be made with the Orbiter's tail cone removed so that engineers could evaluate the handling qualities under the adverse aerodynamic conditions. Up to three tail cone-off descent flights would then be performed to demonstrate a steep 24° glide path such as will be required of Orbiters returning from space; with the tail cone on only 9°-12° glideslopes are possible. With completion of the last descent flight in January 1978 the Orbiter would be cleared for ground tests at the Marshall Space Flight Center. Two captive-inactive flights would be made before the long trip to Alabama in the March.

The first flight under Phase 1 got under way on 18 February from runway 04 heading in a north-east direction and the Orbiter/SCA assembly weighed 264.9 tonnes at takeoff. The configuration was airborne at 142 kt following a 1,830 m run and pilots Fulton and McMurtry soon found handling characteristics, particularly stability, to be in excess of the simulator predictions with very little input from the 65.14 tonne Orbiter on top of the SCA fuselage. After climbing to 4,900 m the assembly performed flutter and autopilot tests followed by an airspeed calibration with a specially modified A-37 aircraft alongside.

With speed at 250 kt the SCA began evaluating stability, control and load measurement conditions prior to descending to 3,050 m, and a speed of 174 kt, for airspeed calibration at a variety of landing gear and flap positions. From this altitude the assembly began a practice landing approach and finally touched down on runway 04 at a speed of 143 kt more than 2 hr. after takeoff. Approach was made on a 3° glideslope and throughout the flight engineers Horton and Guidry monitored critical systems on the Boeing 747 from their respective positions on the flight deck. Of 18 test points on the first flight all but one, a thrust moment balance test to evaluate performance during asymmetric engine output, had been successfully achieved.

The second flight of the six planned under Phase 1 came on 22 February, just four days after the first. When the Orbiter/SCA assembly lifted into the air at a speed of 142 kt at 8.32 a.m. it weighed 283.7 tonnes and carried fuel for what would be the longest flight of the entire series. Because

At the Dryden Flight Research Center, Edwards, California, the 122 ft. (37 m) long Space Shuttle 'Enterprise' is mated to the 747 Shuttle Carrier Aircraft. The Orbiter was hoisted in a specially designed Mate-Demate facility and the 747 was towed underneath. The Orbiter was then lowered and mated to the 747 at three attachment points.

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of the extra weight rollout used 1,990 m of runway 22, selected for this flight due to a gusting north-west wind; a T-38 chase-plane had been sent up earlier to check on wind patterns at the expected SCA operating altitude. The flight was primarily intended to explore the flutter regime at altitude up to 6,700 m, evaluate stability and control characteristics and complete airspeed calibration tests begun on the first flight.

Buffet checks were carried out as the combination climbed through 220 kt and at 4,880 m flutter, airspeed and stability checks were performed at 250 kt and 267 kt. From here the Boeing climbed to 6,700 m and a similar run of checks at 210 kt, 245 kt and 265 kt before descending to 4,880 m again for a third set of tests at 277 kt and 285 kt. In Phase 3 flights the Orbiter would be released at a speed of up to 278 kt but simulator runs had shown up a maximum 10 kt increase when the Orbiter was separated and engineers were keen to qualify the assembly at speeds of up to 288 kt.

By the time the second flight was over the crew had successfully performed 30 test points including the thrust moment balance test cancelled on the first flight. The 3 hr. 13 min. flight had been exceptionally successful, marred only by a delayed takeoff due to a minor problem with the auxiliary power unit. Test objectives were being met so efficiently that Donald K. Slayton, ALT programme manager, considered cancellation of the sixth flight if the next three performed as well as the first two.

The third flight got off the ground on schedule on 25 February. Tests concluded the extensive flutter and stability checks and this time were measured during shallow dives from 4,880 m, 7,320 m and 7,930 m with a maximum speed of 292 kt, well in excess of the planned Orbiter separation speed for Phase 3 and above that predicted on the unloaded overrun following simulated release in ground computers. Immediately after takeoff the outer starboard engine was throttled back to idle thrust and the remaining three motors carried the assembly to a height of 1,530 m at which point the No. 4 engine was brought up to power again. During speed tests at 280 kt the pilots noticed a considerable increase in buffeting brought about by the aerodynamic matching of the Orbiter with the tail of the Boeing 747 and

at one time the T-38 chase pilot reported a visual ripple effect on the Orbiter's tail cone, carried only to smooth airflow across the boattail. Planned separation speed of 278 kt was just below the region of increased buffet and was expected to cause no problem during the Phase 3 drop tests. Any speed overrun experienced by the Boeing at release would be free of the Orbiter induced buffet.

At the end of the 2½ hr. flight Donald Slayton confirmed cancellation of flight 6, re-asserting his confidence that all objectives would be met with the next two tests; instead of flights 4, 5 and 6 on 1, 4 and 8 March, flight 4 would be moved up to 28 February and the last captive-inactive flight would be flown on 2 March.

The fourth flight was airborne at 8:00 a.m. local time on 28 February with a direct ascent to 7,620 m and a series of dives simulating the profile to be flown by Phase 3 drop test runs. Spoilers were put out during these manoeuvres to various positions in drag and handling checks on the performance of the mated configuration. In addition, spoilers were put out at a speed of 288 kt with very little noticeable effect superimposed on the Orbiter-induced buffeting familiar at this speed and first sensed on the previous flight.

From a height of 7,620 m the four Boeing 747 engines were set to a special thrust rating which carried the assembly up to more than 8,700 m, the highest altitude reached on any ALT flight so far. Here the Orbiter/SCA began another simulated separation dive, *albeit* shallow, down to a height of 6,705 m for more spoiler tests and an emergency descent test with all four Boeing engines cut back to the idle position. Holding a 5° pitch to prevent an overspeed situation the assembly dropped to a height of 4,880 m preparatory to the approach glideslope to runway 22. The flight ended with a test of an emergency landing abort, the assembly holding off the runway at a height of 6 m for a go-around test on full power. On the second run in the SCA touched down for a minimum roll on full braking. This was performed to qualify landing roll-out in a distance compatable with the 2,280 m runway at the Marshall Space Flight Center which will receive the Orbiter/SCA combination after ALT flights are over and Orbiter 101 is delivered to that facility for ground vibration tests.

The final captive-inactive flight came on 2 March, just 12 days after the first, and was designed to fully simulate two separation flight profiles. With a loaded weight of 250.39 tonnes the assembly climbed to a height of 8,717 m and began a -5.7° pitch-over to a separation speed of 280 kt. Just as on the actual separation profile of the Phase 3 tests the pilot reduced the engines to idle and put out the spoilers although full countdown-to-release terminated just short of firing the explosive attachment bolts; Orbiter segments of the countdown would be performed in the Phase 2 captive-active series. The planned altitude at the start of the separation manoeuvre was desired to be between 8,380 m and 8,840 m with a preferance for the higher value and the first simulated run had demonstrated this capability. The second simulation began with the Orbiter/SCA climbing back up from the dive altitude and on this attempt the assembly reached 9,140 m, well in excess of the scheduled height window for drop tests.

Astronaut Fred Haise (left) laughs at a piece of burnt toast presented to him at a pre-flight breakfast on 12 August 1977 at the Dryden Flight Research Center. Following breakfast he and Gordon Fullerton (centre) piloted the Shuttle 'Enterprise' on its first free flight.

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Data from this and preceding tests indicated that the positive separation force would approach 0.8 g at Orbiter release, certainly on the high side for good climb-out after leaving the SCA; any increase in this value would cause the Orbiter to pitch up, lose forward speed and move rearward relative to the SCA with consequent danger of an impact with the Boeing's tail. At the end of the flight the assembly was brought to a halt after minimum roll to further demonstrate a capability to land on the 2,280 m long runway at the Marshall Space Flight Center.

ALT Phase 1 Results

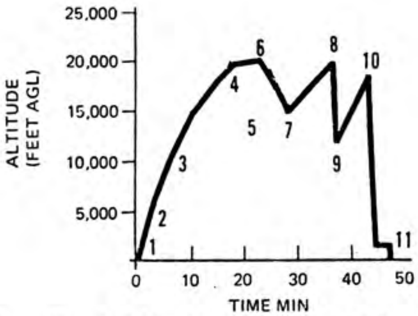
After only five captive-inactive flights Phase 1 of ALT activities had proven SCA/Orbiter capabilities and demonstrated superior aerodynamic handling qualities to those anticipated before the series began. Under the original schedule Phase 2 would follow with five flights in a captive-active series where two astronauts would be situated on the Orbiter's flight deck in addition to the four crew members in the Boeing 747. It had been necessary to accelerate preparations for Phase 1 so that the four astronauts assigned to Phase 2 and Phase 3 tests could benefit from engineering and aerodynamic data acquired in the captive-inactive trials. Much time had still to be spent in the simulator at the Johnson Space Center rehearsing separation and descent tasks; computer and math model predictions on the performance of the dual configuration were simply not good enough for accurate simulator inputs and the actual flight measurements of the five Phase 1 tests were essential for final refinements in the computer controlled simulator.

Because of this, Phase 1 had "leap-frogged" several important certification schedules for Orbiter systems and qualification of on-board equipment, plus the fitting of subcontractor elements which had not yet been installed, would have to be completed before Phase 2 could get under way. Readers will recall that the five Phase 2 captive-active flights were originally scheduled to begin 26 May. It soon became apparent that date could not be met and while astronauts Haise, Fullerton, Engle and Truly spent many hours in the simulator rehearsing the all important separation tasks engineers performed final equipment installation and final subsystems certification was signed off preparatory to freeing Orbiter 101 for Phase 2 where many engineering tests would be performed in flight while still mated to the Boeing 747.

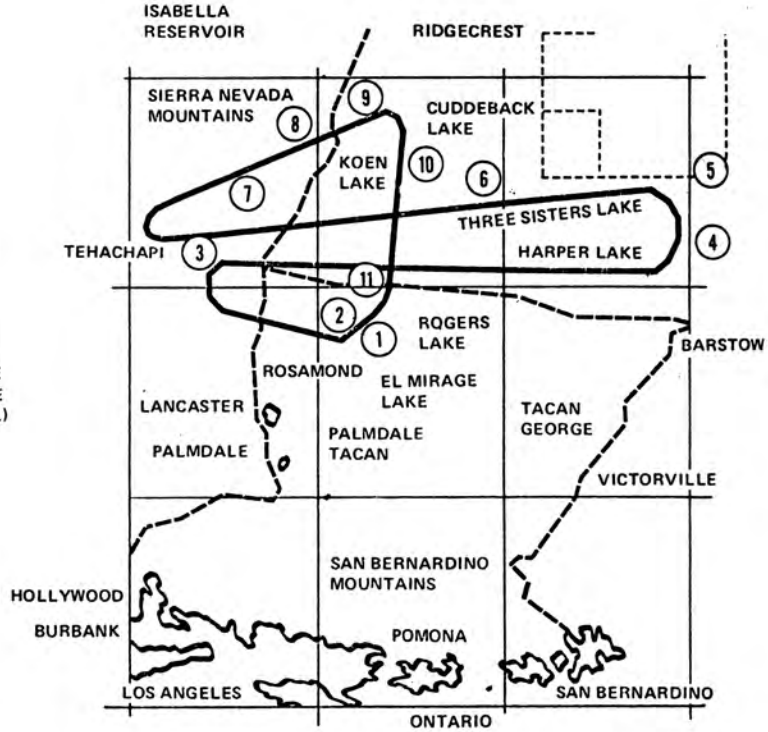
Before ALT tests began it was believed that time would have to be spent between Phases 2 and 3 in replacing the elevon actuators which required de-mating the assembly and then re-mating the Orbiter to the SCA. Also, it was believed that retraction of the Orbiter undercarriage could not be performed with the two structures mated and since the final flight in Phase 2 was expected to call for active Orbiter undercarriage deployment considerable activity in the de-mated condition threatened to prolong the time between Phases 2 and 3 (there is sufficient clearance for the Orbiter to deploy its undercarriage while still attached to the SCA

ALTITUDE PROFILE

NOTE
ALTITUDES ARE ABOVE GROUND LEVEL(AGL)AND ARE REFERENCED TO ORBITER GROUND AIM POINT ON THE RUNWAY (ADD 2300 FEET TO OBTAIN MEAN SEA LEVEL)



GROUNDTRACK



Space Shuttle Orbiter/Boeing 747. Fig. 1 *(above)*. Mated Profile Captive Active 2. Fig. 2 *(below)*. Mated Profile Captive Active 3.

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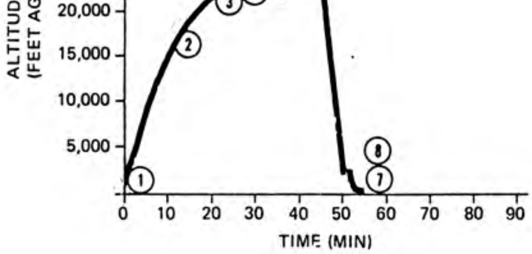
FLIGHT SEQUENCE

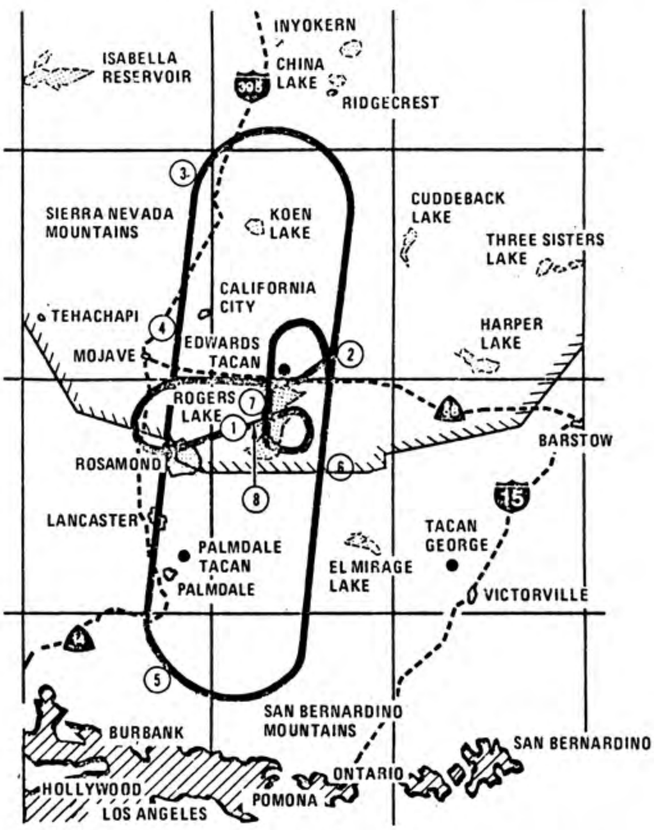
Item	Time (min.)	Altitude (feet AGL)	Range (NM)	Event
(1)	0	0	0	SCA takeoff
(2)	13	16,905	12	Intersect racetrack
(3)	24	22,705	26	In-flight FCS checks
(4)	28	23,605	16	Reach MCT 200 FPM ceiling
(5)	36	24,705	29	SCA begin SRT
(6)	45	25,905	9.5	Pushover (practice SEP)
(7)	55	0	0	SCA touchdown
(8)	55.5	0	0	Deploy landing gear during SCA rollout at -125 KCAS

ALTITUDE PROFILE

NOTE: ALTITUDES ARE ABOVE GROUND LEVEL (AGL) AND ARE REFERENCED TO ORBITER GROUND AIM POINT ON THE RUNWAY (ADD 2300 FEET TO OBTAIN MEAN SEA LEVEL)



GROUNDTRACK



and evaluation of this system would be the final pre-drop test qualification activity).

While it had been important to accelerate Phase 1, and not unduly troublesome to experience delay in starting Phase 2, programme officials were mindful of the need to move quickly from Phase 2 to Phase 3. So they devised a method of retracting the Orbiter undercarriage in the mated configuration and spent the time between Phases 1 and 2 replacing the elevon actuators, effectively clearing obstacles to moving from Phase 2 to Phase 3 without de-mating the configuration. By May final details had been put to flight plans for Phase 2 captive-active tests and this incorporated a reduction from five flights to four. The first would be flown in mid June and adopt a racetrack pattern for a period of 49 min. with the assembly flying to 4,570 m. Flutter checks, Orbiter speed brake (split rudder) tests and TACAN (Tactical Air Navigation System) trials would be attempted at a limiting speed of 180 kt. The second flight would reach 7,225 m and 280 kt, use a larger racetrack pattern and simulate a pre-separation manoeuvre during a 60 min. schedule. The third flight would take the assembly to separation conditions, use a similar racetrack pattern to that adopted for the second flight and land 62 min. after takeoff. The fourth flight would last 55 min. and fully rehearse all the characteristics of a Phase 3 separation with Orbiter undercarriage deployment on the run after touchdown.

Emergency Procedures

Meanwhile, at Holloman AFB New Mexico, the Orbiter escape system successfully passed active tests on a rocket sled. At a rail speed of 300 kt the ejection seat flew away from the Orbiter nose mockup (Space Shuttle Escape System Test Vehicle) and brought its dummy occupant safely down to the ground. This ejection system has been developed from that employed on the SR-71 and is standard on the first two Orbiters.

Also at this time the two emergency egress paths were tested from the Orbiter mockup at the Johnson Space Center. The primary route is *via* the 102 cm diameter side hatch which contains a folding boom assembly and a 15 m long nylon rope. As the side hatch is lowered the door converts into a platform whereupon the boom swings out and unreels its rope to the ground. A hook and control clutch allows the crew member to descend at constant speed. If this system is deemed excessively time consuming to escape a potential hazard the overhead ejection panels in the roof of the crew cabin are jettisoned from where 23 m long ropes provide sliding access to the ground down the sides of the Orbiter and the SCA. In both escape paths the astronauts can use face masks and an emergency back-mounted oxygen system. These paths are only applicable to Orbiters mated to the Boeing 747 since they operate on the premise that the vehicle is in a horizontal position; 10 years on from the apalling fire that took the lives of three Apollo astronauts NASA is determined to cover every conceivable contingency with an adequate escape system.

Phase 2 Tests Begin

Back at the Dryden Flight Research Center final preparations were being made for Phase 2 tests. Delays in qualifying the hydrazine fuelled Auxiliary Propulsion Units helped push the scheduled start 22 days beyond the original plan. However, three problems on 17 June caused a further 24 hr. postponement: coupling links securing the overhead ejector seat panels to the roof of the Orbiter cabin proved troublesome, one of the three on-board inertial measurement units failed and two of the four primary flight control computers packed up.

Original plans for the first captive-active flight envisaged a takeoff toward the north-east on runway 04 but winds on 18 June caused a 180° switch to runway 22. As dawn broke across the dry, flat landscape preparations were well advanced and the Orbiter/SCA assembly was slowly backed out of the Mate-Demate Device (see above). By this time all Orbiter systems had been activated, the four computers were running normally but only two of the three IMU's were operating – a safe condition for these early mated flights, however. As the assembly was being backed away from the MDD, preparatory to its being towed to the ramp for engine start, the big Boeing sucked in toxic fumes from ammonia boiler vent tubes on the Orbiter. This necessitated the SCA crew putting on oxygen masks and sealing off the cabin air vents.

With Fulton, McMurtry, Horton and Guidry in the 747 and Haise and Fullerton in Orbiter 101 the 265.36 tonne configuration was manoeuvred to the ramp about one hour before the planned takeoff time of 8:00 a.m. By now control of the flight had switched from Dryden to the Johnson Space Center at Houston but a 4 min. delay was brought about by uncertainty as to who should clear the Boeing crew on to runway 22. A further 2 min. was lost waiting for the T-38 chase planes to re-group their approach patterns so that they would join the assembly at SCA brake release. Finally, at precisely 8:06 a.m., the massive assembly began a 1,830 m roll to takeoff and the configuration, now weighing 263 tonnes, gracefully swept into the sky. Because the takeoff had been made in the opposite direction to that planned for joining the racetrack test pattern some 14 min. was lost in manoeuvring round to the correct heading.

All Orbiter systems, including APU, hydraulic, coolant and electrical (using liquid propellants in the fuel cells instead of cryogenics for orbital flight) performed well and the assembly reached a height of 4,562 m at which point the Boeing crew set 10° flap positions because of the low, 180 kt, speed. During the climb the Orbiter vent valve stuck and crew action was required to bring the cabin down to two-thirds atmospheric sea level pressure as detailed in the flight plan. Orbiter flight control system checks were also performed with little overall effect on the stability of the dual configuration. The racetrack flight path was about 125 km long with 180° turns at each end adopting 16 km curves.

After the first turn the split rudder was used to test speed brake functions at the 60, 80 and 100% positions, the latter providing each opposing panel with a 45° deflection to set up an angle of 90° with its neighbouring panel. At the 100% position drag was pronounced and required Fulton to place Boeing engines at the climb setting to maintain altitude and speed. More tests followed before the racetrack pattern was completed and the assembly landed with a weight of 249.5 tonnes to successfully conclude the first captive-active flight. It had lasted just 55 min. 46 sec.

Examination of the flight data indicated that the Phase 2 programme could conceivably be reduced from four flights to three if the second performed as well as the first. The second would come on 28 June, the third on 8 July and the fourth on 15 July under the original schedule but planners increased the test objectives for the second ascent in the hope of reducing the Phase 2 series and making up lost time from the delayed interval between captive-inactive and captive-active phases; flights two and three would, in effect, be combined on the second run. Astronauts Engle and Truly were on the Orbiter crew compartment flight deck when the second flight began at 07:50 a.m. on 28 June. The groundtrack would comprise a complex series of patterns originating and terminating in the south-west direction from runway 22 (see Fig. 1).

Shortly after the 253 tonne assembly became airborne flutter tests were conducted at a speed of 230 kt followed by 60, 80 and 100% Orbiter speed brake settings. The assembly lost speed at the 60% setting and climb rate was stopped altogether at the fully open position. With the

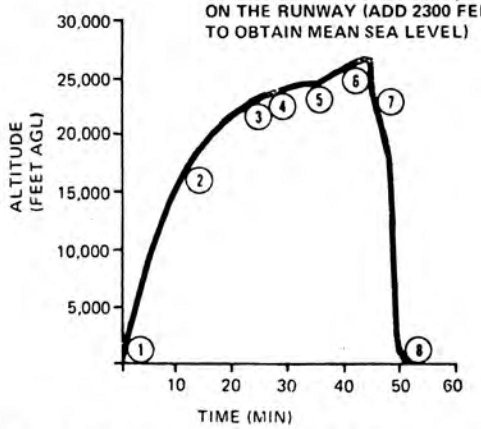
FLIGHT SEQUENCE

Item	Time (min.)	Altitude (feet AGL)	Range (NM)	Event
(1)	0	0	0	SCA takeoff
(2)	12	16,400	8	Intersect racetrack
(3)	22	22,000	32	In-flight FCS checks
(4)	28	24,100	14	Reach MCT 200 FPM ceiling
(5)	35	24,100	31	SCA begin SRT
(6)	45	26,500	9	SCA pushover
(7)	46	22,800	7	SCA orbiter separation
(8)	51	0	0	Orbiter touchdown

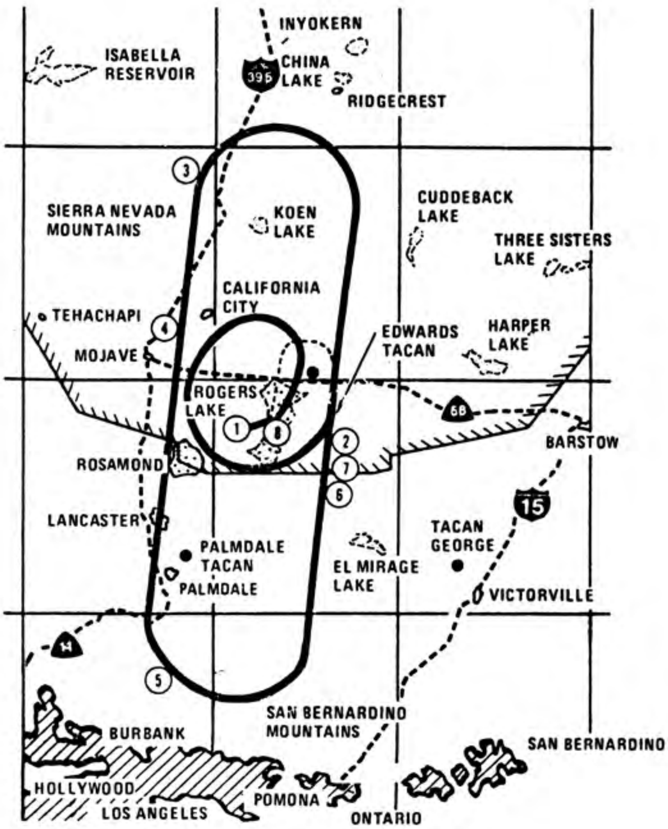
Note: There is only one full go around if the Orbiter does not separate on the first attempt; the flight will be terminated.

ALTITUDE PROFILE

NOTE: ALTITUDES ARE ABOVE GROUND LEVEL (AGL) AND ARE REFERENCED TO ORBITER GROUND AIM POINT ON THE RUNWAY (ADD 2300 FEET TO OBTAIN MEAN SEA LEVEL)



GROUNDTRACK



Space Shuttle Orbiter/Boeing 747. Fig. 3. Mated Profile Free Flight 1.

brakes closed the Orbiter/SCA combination continued on up to 5,880 m and a speed of 260 kt using the special rated thrust setting in the four Boeing 747 engines. From here a second set of flutter tests was performed followed by push-over and acceleration to 270 kt with more speed brake inputs at the 60, 80 and 100% settings, the combined product of which lowered altitude to about 4,600 m.

With Boeing engines set back to the maximum continuous power setting the assembly increased its height to 6,190 m preparatory to beginning a separation manoeuvre test profile. The pushover increased speed to 270 kt again with a descent rate of 914 m/min. and the Boeing's engines were set at idle, the spoilers were put out and the Orbiter trimmed its elevons to + 1.5°, 0° and - 1.5° positions in attempts to provide data for settings on the actual drop tests to be conducted later under Phase 3.

Down now to a height of 4,175 m the assembly began a turning climb back to 5,880 m for the final major test, an AUTOLAND calibration run across the microwave scanning beam landing system (MSBLS) which would be used to provide position information to the Orbiter during Phase 3 free flight tests and below 3,000 m for subsequent Orbiters returning from space. Between the climb to 6,190 m for the pre-separation run and the 4,175 m level the assembly had been flying a straight course south of the Sierra Nevada mountains in a north-easterly direction. The ascending turn brought the heading almost due south for the final descent to the Dryden complex.

As the assembly swept in to the MSBLS network on runway 17L the Boeing crew deployed the SCA's undercarriage and air brakes to set up a 6° glideslope while the Orbiter crew monitored the Horizontal Situation Indicators tied in to the MSBLS beams. At a height of 915 m the Orbiter/SCA flared for the landing slope and came down on runway 22 more than an hour after takeoff. Unfavourable winds at Dryden caused re-designation of the ramp used for systems shutdown, thus preventing hydrazine and ammonia fumes from blowing into facilities at the base. During de-activation procedures a major APU leak was detected in the same system components that had exhibited minor leaks before Phase 1 ALT flights began.

Due to this and the need to perform engineering tasks on Orbiter 101 before it could be committed to free flight activities planners decided to schedule the third and final Phase 2 test for 28 July, exactly one month after the second. This would enable the main landing gear actuators to be replaced and provide sufficient time for two backup (378 litre) hydraulic reservoir tanks to be installed, APU's 1 and 2 to be changed and the No. 5 (general purpose) computer to be replaced. The extended interval between Phase 2 flights two and three incorporated the 15 day modification period originally planned for the period between Phases 2 and 3. If the third Phase 2 flight was successful the first free flight test of Phase 3 would be attempted on 12 August.

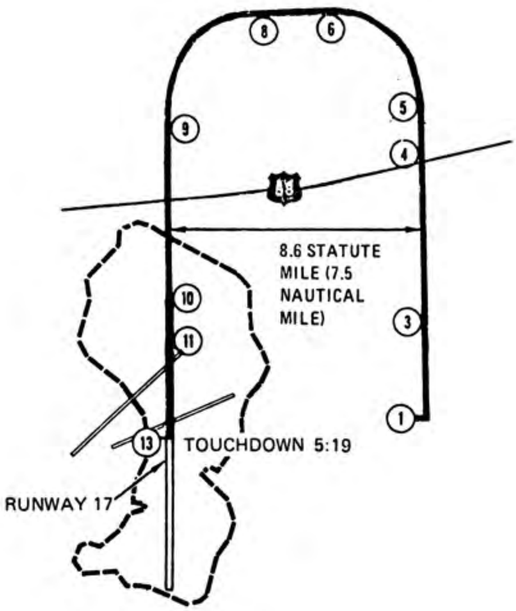
As it turned out NASA was able to back the date of the final Phase 2 flight up 48 hours to 26 July and at precisely 7:47 a.m. local time the 256.5 tonne SCA/Orbiter 101 assembly accelerated down runway 22 and into the air. The groundtrack for this final captive-active flight incorporated a racetrack pattern with 135.2 km straight-ways and 38.9 km curves at each end, in almost exact duplicate of the pattern to be flown by the first free flight test several weeks later.

FLIGHT SEQUENCE

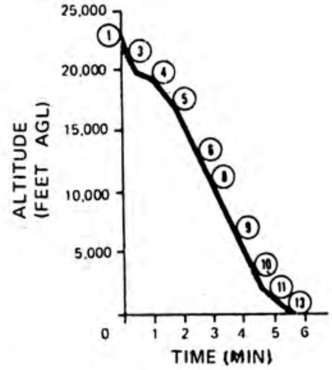
Item	Time (min. sec.)	Alt. (AGL)*	Keas	Action
(1)	0:00	22800		Separation
(2)	0:03	22500		Roll right
(3)	0:23	20400		Initiate practice flare
(4)	1:15	19700		
(5)	1:35	17000		Roll left
(6)	2:12	13500		Roll to = 0
(7)	2:32	10600		
(8)	2:34	10300		Roll left to line up on runway
(9)	3:20	7500		Turn complete hold airspeed = 270; speedbrake = 30%
(10)	4:26	2000		Speedbrake = 0
(11)	4:43	900		Initiate preflare
(12)	4:58	180		At airspeed = 250, deploy gear
(13)	5:19	0		Touchdown
(14)	5:29	0		At airspeed = 115 moderate braking
(15)	5:48	0		At airspeed =60, engage NWS

* *Note:* Add 2300 feet to obtain mean sea level.

GROUNDTRACK



ALTITUDE PROFILE



ORBITER WEIGHT = 150,000 POUNDS
TAILCONE ON (68,040 KILOGRAMS)

Space Shuttle Orbiter/Boeing 747. Fig. 4. Free Flight 1.

The prime purpose of the flight was to perform a full simulation of the timeline to be adopted for the all important drop test (Fig. 2). Again, Orbiter electrical, APU, hydraulic and coolant systems were powered up and astronauts Haise and Fullerton were on the flight deck.

Shortly after takeoff, and in the early stages of a climb to 9,000 m, the caution and warning displays informed the Orbiter crew of excessively high temperature in the No. 1 APU exhaust system and the power unit was shut down by Fullerton as dictated by the flight rules. Telemetry read out on the monitors at the Mission Control Centre in Houston exposed a malfunctioning sensor rather than a faulty unit and the flight continued. During the initial portion of the climb the Orbiter flight control system and aerodynamic control surfaces were exercised just as they would be on a drop test.

About 15 min. after takeoff the assembly turned on to the designated racetrack pattern and headed almost due north then flew the 38.9 km curve to port, turning 180° in the process to follow the 135.2 km long southern leg of the straightway. Turning again to port for another 180° change of heading 20 minutes later the Boeing crew applied the special rated engine thrust and raised altitude to 9,233 m; during the intervening period checks had been performed with the Orbiter TACAN system which will be used to track Orbiters returning from space down to the 3,000 m point where the MSBLS takes over.

Less than 48 minutes after takeoff the assembly pitched over, accelerated to a speed of 270 kt and followed an identical procedure to that which would be used on the initial Phase 3 free flight tests. At the point of simulated separation the assembly was 13.9 km to the right of runway 17 just as it would be on the first drop test. From this point on the mated configuration followed a U-shaped trajectory, losing altitude at a similar rate to that which the Orbiter would programme when it separates from the Boeing.

Following a precursor path toward runway 17 the assembly levelled off at about 700 m and continued on over the runway, performed two left turns in a wide sweeping circle and touched down on runway 22. During the rollout, and while the Boeing's nose wheels were still off the ground, the Orbiter crew lowered the landing gear for the first time in an ALT test and qualified the system for use on free-flight descents. In this third captive-active flight the SCA had carried the Orbiter along a pre-separation groundtrack path, simulated an actual separation manoeuvre and then descended along a similar path to that which the Orbiter would perform on its own during Phase 3 activities.

But just as Phase 1 had in practice been accomplished in five flights instead of the originally planned six, and Phase 2 on only three tests instead of the expected five, so it was with Phase 3. There was good reason to quicken the pace and move toward conclusion of the ALT series as soon as possible. Early release of Orbiter 101 from its ALT and ground

vibration tests would ensure the ready availability of this vehicle to supplement Orbiter 102 space operations from early 1981; about 2½ years would be needed to refurbish Orbiter 101. Under the original plan, Orbiter 101 would perform five drop tests with the tail cone on, a single captive-inactive flight to check stability with the tail cone off and three drop tests in this configuration. At maximum, Slayton felt, only three tail cone-on flights were really necessary followed by one tail cone-off flight. Early termination of the ALT activities would release personnel for other critical Shuttle activities but by just how much the planned flight schedule could be reduced in reality would only become apparent after at least two drop tests.

First Phase 3 Free-Flight

As 12 August approached preparations for the first Phase 3 free-flight test went smoothly ahead and final details were added to the flight plan. Thousands of visitors came in on roads leading to the Dryden Flight Research Center, many people camping out all night to see the drop test. Long before dawn on 12 August the gates were opened and a long procession of cars slowly moved into the main complex. In all, more than 60,000 people would watch the proceedings.

By now the terminal countdown was on and shortly after 6:00 a.m. Haise and Fullerton climbed into the Orbiter's flight deck. The only problem encountered had been a failure in the No. 3 computer but the unit was soon changed. Minutes after crew ingress the ammonia system was activated and the fuel cells transferred to liquid reactants stored in the cargo bay from ground supplies that had powered the units up. With less than an hour to go before takeoff the assembly was backed out of the MDD and slowly moved to the NASA ramp for engine start-up. With half an hour to go the Boeing taxied out to runway 04 and waited while Haise and Fullerton performed control system checks from the Orbiter flight deck.

Right on time at 08:00 local time (16:00 BST) the brakes were released and the big assembly trundled off down the runway. The climb to altitude was hampered by high atmospheric temperatures, requiring 3 min. extra time to reach pushover height. During the ascent the Boeing executed a near continuous bank to port to join the designated race-track due east of Rogers Dry Lake, itself east of the Orbiter landing site: runway 17. Just 4 min. into the flight the Orbiter cabin was pegged at two-thirds sea level pressure followed by activation of the third auxiliary propulsion system and flight control system checks. Special rated thrust on the four Boeing engines was brought in as scheduled to put the assembly at a height of 8,539 m just 47 min. after takeoff.

At this point the Boeing entered a -7° pitch attitude to set up a -9° descent path to the separation speed. The Orbiter crew had set in a programmed 2°/sec. pitch-up rate which would be executed at separation. At a speed of 280 keas (kt equivalent air speed), and at a height of 7,346 m, the Boeing pilot called out a launch ready situation to Haise and Fullerton. From their position above the Boeing, totally unable to see any of the SCA's structure, the Orbiter crew fired the separation bolts and lifted cleanly away on independant flight just 48 min. 28 sec. after takeoff. The only anomaly at separation was a spurious readout from the No. 2 computer but with four back-up units this was no problem.

When mounted on the SCA, Orbiter 101 was in a +6° pitch position due to the geometry of the three interface struts. This provided the Orbiter with a -1° angle of attack at separation due to the -7° pitch in the Boeing system. The programmed pitch rate of 2°/sec. at the instant of separation would be held for 3 sec. and push the nose up 6° above the pre-separation angle of -1°. In this way the Orbiter would stabilise at +5° pitch just 3 sec. after separation before rolling to the left while the SCA turned to the right. As it turned out, Haise noticed a pitch rate drop-off to 1°/sec. but quickly restored the programmed rate of 2°/sec. for 3 sec. with manual commands.

Seconds after release the Orbiter was in the desired attitude and rolling to the right to provide good lateral separation from the SCA. This was followed immediately by a left roll to level off the wings again for a -9° pitch on a heading of 350°. From this point on the Orbiter would perform two 90° left turns and level off for touchdown on runway 17 (Fig. 4). Throughout these manoeuvres there was a continuous dialogue between the crew and controllers at the Johnson Space Center; information was fed into computers throughout the descent phase to provide performance and stability predictions. Considering the brief 5 min. period of the descent this was no mean feat.

Before executing the first 90° turn Haise put the Orbiter through a practice flare and negotiated a series of banking manoeuvres, *albeit* limited to 10°, to evaluate the response of the control surfaces to a random input situation. During these the lift values were calibrated with the Orbiter in a +11° pitch attitude. An important function of the exercise involved real-time predictions from the Johnson Space Center so that ground controllers could advise the Orbiter crew of any indicated changes to the L/D values which they would need to be aware of before conducting the landing flare. Misinterpretation of descent and altitude gain rates led the JSC controllers to the conclusion that Orbiter L/D was less than that predicted and this information would be responsible for a moderate overspeed situation at touchdown. The Orbiter actually climbed in altitude during the pre-flare test whereas JSC was assuming that the vehicle was in level flight. Speed dropped from 250 keas at the start of the manoeuvre to about 185 keas at exit.

Back-up to 250 keas, Haise relinquished control to Fullerton who took the Orbiter round the first 90° turn. Both pilots noticed a crisp response to inputs and found a more positive control function than that experienced in the Grumman Gulfstream 11 Shuttle Training Aircraft. Now, more than 2 min. after separation, the Orbiter was on the base leg of the approach phase and down to a height of about 4,800 m. Little more than 20 sec. later the second 90° turn, controlled this time by Fred Haise, brought the Orbiter round to the final approach leg with the speed brakes (split rudder) out to the 30% position. This provided a total split rudder angle of 27° although the flight plan had required the turn to final to be accomplished without the use of the speed brake facility. When the Orbiter rolled to wings-level for the final approach, speed was down to 255 keas but this began to increase as expected.

On emerging from the second 90° turn Haise acquired visual inspection of the approaching runway, noted that the Orbiter was too high and building excess speed and commanded 40% speed brake (total split rudder angle of 36°) to dump lift. But still the Orbiter accelerated. At 270 keas Haise put in a 50% speed brake setting (total angle of 45°) and held the original aim point, knowing that the final flare would carry the Orbiter several hundred metres beyond the scheduled touchdown line. It was rapidly becoming apparent that the Orbiter possessed the expected L/D values and that the predicted excess drag was an anomalous real-time calculation based on incomplete data.

There was nothing Haise could do. As speed built up it would have been possible to dump excess energy by applying high-angle speed brake settings but the 50% value was a mission constraint induced by reluctance to introduce steep glideslope angles on this first flight. The build up in speed finally decreased at 285 keas (15 keas over the pre-flight prediction due to in-flight assumption that the Orbiter was low on lift) and Haise began the landing flare from a height

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SPACE EXPLORATION AT THE SCIENCE MUSEUM

By Dr. E. J. Becklake*

Introduction

Set among her sister museums at South Kensington in London, the Science Museum had been collecting and displaying objects of scientific interest for over a hundred years. As well as her traditional involvement and expertise in the history of Science and Technology, the Museum is actively concerned with the scientific achievements of the present. A good example of this is the new exhibition on the general theme of 'Exploration' that opened at the Science Museum in December 1977. The exhibition will last for at least three years. A small Space Science and Technology Collection has also been in existence at the museum since the early 1960's. This Collection and the problems involved with Space Science as a museum subject will be discussed in a later article.

The Exploration Exhibition

This project is something of a departure from normal Science Museum practice, being a multi-disciplinary exhibition dealing with subjects at the forefront of present-day endeavour. It occupies an area of some 1,200 square metres, equal to about four tennis courts, on the ground floor. The word "exploration" is used in its widest sense, as the exhibition demonstrates how man uses his scientific and technical skills to investigate the inaccessible, the impenetrable and the invisible.

The exhibition is divided into six sections: Man on the Moon, The Planets and Beyond, Medical Science, Remote Sensing, Climatology and Underwater Exploration, and each section tells the story of one aspect of modern man's exploration of the world around him. The topics were selected to show the vast range of man's activity, from his study of the depths of the ocean to his exploration of the borders of the known Universe.

The first two sections are the ones dealing with space exploration. The Medical Science area introduces four techniques, the EMI X-ray scanner, endoscopy, ultrasonics and psychology, used by doctors to explore our minds and bodies without the use of a scalpel. In Remote Sensing we show how man uses his new electronic senses to learn more about the world around him. By looking at everyday objects at wavelengths outside the range of our eyes the world is seen in a "new light." The Underwater Exploration section deals with that 70% of our globe beneath the oceans; and in Climatology we show how scientists are using clues hidden in such odd places as tree rings, ice caps, deep sea cores and harvest records to explore how our climate has changed through the ages.

Man on the Moon

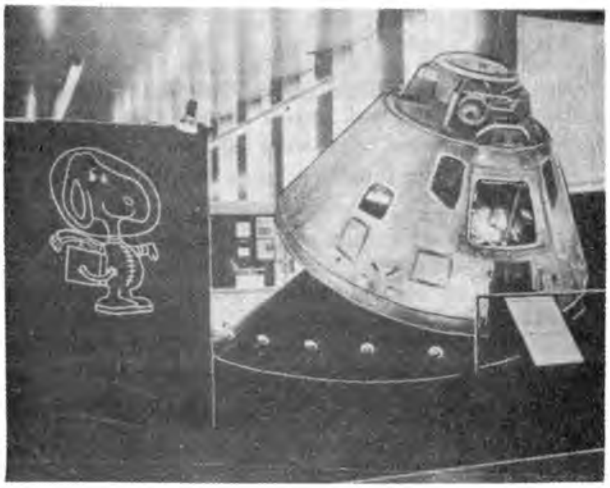
The most spectacular feat of exploration ever undertaken by man was the flight of Apollo 11 to the Moon. The crew of Apollo 11, Neil Armstrong, Edwin Aldrin and Michael Collins, have secured for themselves a place in history alongside the famous explorers of the past such as Magellan and Marco Polo. This section traces the story leading to this voyage and man's first steps on another celestial body.

A full size model of the Lunar Module standing on a simulated lunar surface is the centrepiece. The Lander, built by Westbury Designs at Pinewood Studios, fits into the six metre high gallery with just centimetres to spare, and more than once we have had cause to thank the original designers of the Lunar Module who incorporated crushable shock absorbers into the legs. This allowed us some artistic licence in deciding the actual height to build our Lander to ensure that it would fit into the gallery.

The display is designed to resemble the first manned base on the Sea of Tranquillity as closely as possible, and two spacesuited figures, representing Armstrong and Aldrin, are included together with models of the experiments they placed on the Moon. A life-size mock-up of the Lunar Rover used on the last three Apollo missions is shown in one corner.

Although the visual side centres around "Tranquillity Base," the section as a whole is more concerned with the problems that had to be overcome before the flight of Apollo 11 became possible than with the actual flight itself. The section takes as its starting point President Kennedy's challenging speech of May 1961 when he committed America to landing a man on the Moon and bringing him back safely to Earth before 1970. To most people this sounded an impossible task. America's space launch vehicles of 1961 were small and somewhat unreliable. Little was known about the Moon beyond what our Earth-based telescopes could tell us and these were not able to pick out objects less than three hundred metres across. The Russians, of course, in 1959 had managed to photograph the far side of the Moon showing the potential of automatic probes. Although three methods of landing men on the Moon were under consideration in 1961, a final choice still had to be made and all the many practical details fixed. Yuri Gagarin in his 108 minute flight into Earth orbit on 12 April 1961 had proved that man could live in space, but the problems of keeping him alive and well for the week or more needed for a manned Moon landing had still to be solved. These four general problems are considered in this section of the exhibition.

The most important object on display is the original Apollo 10 Command Module that carried astronauts Stafford, Cernan and Young around the Moon in May 1969 on the final rehearsal for the Apollo 11 mission. This capsule has already been exhibited here for over a year and has proved to be one of the most popular exhibits in the Science Museum Other important objects and models on display are listed in Table 1. Apollo 10 and all the manned space artifacts are on



The Apollo 10 Command Module on display at the Science Museum.

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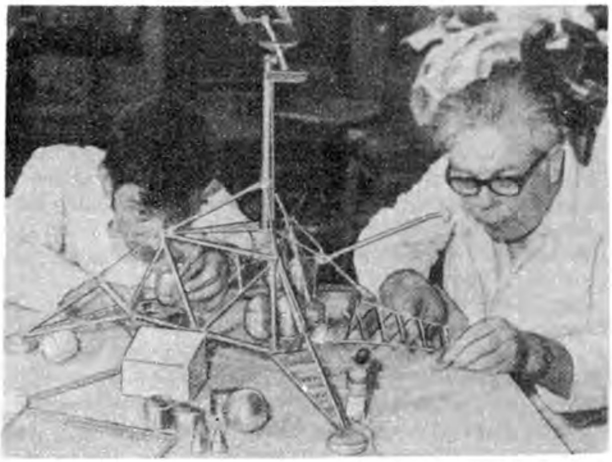
* *Assistant Keeper – Astronomy, Meteorology and Space Science Museum, London. Project Coordinator of the Exploration project.*



A 1/6th scale model of the Surveyor spacecraft being made in the Science Museum's workshop.

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loan from the National Air and Space Museum (NASM), Smithsonian Institution, in Washington who are the official custodians of NASA artifacts.

Many of the spacecraft models shown in this and the 'Planets and Beyond' section were made in the Science Museum's own workshops. The Science Museum prides itself on the quality of its models, a feeling shared by each craftsman as an individual, and every effort was made to produce accurate scale models. Rather surprisingly we experienced great difficulty in obtaining reliable and consistent drawings and photographs that would enable the modelmaker to produce an authentic model of a particular spacecraft. With the notable exception of the Apollo 11 EASEP information provided by Bendix and the Mariner 10 and Pioneer 11 data obtained from Boeing and TRW respectively, we were unable to obtain general arrangement drawings of any of the spacecraft. Much information was acquired from sources in America and Britain, but all too often the pictures showed either a model of the spacecraft rather than the real thing or another spacecraft in the same series which differed in some details from the one being modelled. Also many of the pictures were of the same view of the craft and did not supply the necessary three dimensional coverage. We would welcome any additional information that readers of *Spaceflight* could supply on any of the spacecraft shown in the exhibition.

The Planets and Beyond

This section looks at the recent advances in the exploration of our Solar System and the Universe. There has been a revival of interest in astronomical research since the last war influenced no doubt by developments in radio astronomy and, later, by the use of observatories operating high above our screening atmosphere and by space probes sent to the nearby planets. Part of this section deals with advances in optical and radio astronomy but most of it concentrates on the work of such spacecraft. Since 1961 when Russia's Venera 1 was sent towards Venus, spacecraft from America and Russia have visited all the planets in the Solar System out as far as Jupiter, and America's Pioneer 11 is now on its was to a rendezvous with Saturn in 1979. Many spectacular pictures of the planets taken from these unmanned spacecraft are displayed as well as scale models of the spacecraft themselves. Dioramas of the planets Mercury, Venus, Mars and Jupiter, based on information supplied by these spacecraft, enable the visitor to obtain a space eye view of the planet. The main attraction here will probably be the Mars Room containing a half scale model of the Viking Lander standing on a Martian landscape.

The advent of the space observatory has made many fresh wavelength regions available to astronomers, and

[Concluded on page 40

Table 1. Objects on display in the 'Man on the Moon' Section.

Actual Hardware

Apollo 10 capsule
Apollo and Gemini heatshield samples
Spacesuit worn by William Anders on Apollo 8
Water-cooled undergarment made for Alan Shepard
Lunar overboot made for Eugene Cernan
Medical harness worn by Edward Gibson on Skylab 4
Faecal containment subsystem made for Alan Shepherd
Urine collection and transfer assembly
Apollo 11 solar wind experiment – flight spare model
Apollo 10 parachute

Models

Full size
Lunar Lander, Lunar Rover, Apollo 11 EASEP, Apollo 11 lunar surface camera, Sputnik 1, Lunar 9.
1/6th scale
Vostok, Mercury, Gemini, Soyuz, Ranger, Orbiter, Surveyor
1/48th scale
12 rockets ranging in size from the proposed NOVA to V2

Table 2. Objects on display in the 'Planets and Beyond' section.

Actual Hardware

TD1A satellite-engineering model
Ariel 5 satellite-engineering model
Satellite experiments:
Ariel 5 crystal spectrometer
Ariel 5 X-ray sky survey
ESRO 2 X-ray sky survey
OSO 4 X-ray spectrometer
OSO 4 solar ultra-violet monochromater
OSO 5 solar X-ray spectroheliograph
Skylark V X-ray sky survey

Models

Half scale
Viking Lander
1/6th scale
Mariner 10, Pioneer 11
1/48th scale
Skylab, Venera, Pioneer Venus, Viking (cruise mode), Mariner Jupiter/Saturn
Planetary dioramas:
Mercury, Venus, Mars, Jupiter, Saturn

Space Report/*continued from page 17]*

parts get more or less moisture? Are severe storms and hurricanes in some way linked to solar mechanisms?

Solar and terrestrial exploration can help establish the physical cause and effect relationships between solar stimuli and terrestrial responses. When these relationships are understood, a new tool will be available for weather and climate prediction.

The Earth's ionosphere and ozone layer which protects us from dangerous solar ultraviolet rays are influenced by solar events and conditions in the magnetosphere which these satellites will investigate. The ionosphere must be better understood because of the major impact it has on worldwide communications and precision navigation systems as well as the amount of global ozone.

Although numerous other spacecraft have been probing the magnetosphere since the early 1960's, the ISEE satellites carry instrumentation 10 times more sensitive than any previously flown. Five years ago, the ISEE series could not be flown simply because the required technology did not exist. As a result, much fine detail information essential to understanding the range of Sun-Earth's phenomena, the entire environmental system of Earth, and the interactions between the two is now available with the ISEE spacecraft for the first time.

The earlier missions have shown that our space environment is very dynamic and exhibits changes more drastic than the weather patterns seen near the ground. It is precisely these changes which need to be studied, using instruments designed to operate in close coordination, to establish the complex interrelationships which control our "space weather."

ISEE-A is a 16-sided cylindrical body measuring approximately 1.73 metres (5 ft. 8 in.) across and 1.61 m (5 ft. 4 in.) high. Its main body consists of an 84 cm (1 ft. 9 in.) conical centre tube, an aluminium honeycomb equipment shelf supported by eight struts. The lower end of the centre tube mates with the launch vehicle and the upper end with the ISEE-B.

Certain exposed areas of the ISEE-A and C spacecraft are coated with a conductive green paint developed at Goddard as passive electrical as well as thermal protection to keep the voltage buildup to no more than one or two volts, even as they pass through the radiation belts.

ISEE-B is a circular cylinder, with a diameter of 1.27 m (4 ft.) and a height of 1.14 m (3.5 ft.). Solar cells are mounted on three detachable curved panels. An aluminium honeycomb platform supported by eight struts and centre tube are the main load-carrying portions.

NASA is responsible for the A and C spacecraft, Delta launch vehicle, tracking and data acquisition and data processing. ESA is responsible for the ISEE-B spacecraft and its operation.

Goddard provides orbital computation, attitude determination and spacecraft control support to the ISEE missions during the planned three-year lifetime of the satellites. ESA, in coordination with Goddard, is responsible for preparing, testing and operating the ISEE-B spacecraft and software for manoeuvre determination and computation.

A total of 117 investigators are concerned with all three spacecraft. They represent 35 university, government and industrial organizations in 10 countries.

ISEE-A is a Goddard Center designed spacecraft built, fabricated and tested at Goddard with all its components either made at Goddard or supplied by industries or universities. ISEE-B is an ESA-European Space Technology Center (ESA-ESTEC) satellite whose design was determined through competitive concepts. The STAR consortium of 10 countries supervised construction under contract to ESA, STAR consists of industries in Belgium, Denmark, France, Spain, Germany, Italy, Netherlands, Sweden, Switzerland and the United Kingdom. Dornier Systems in Frederickshaven, Germany, heads the contractor team.

Estimated cost of the two spacecraft and the scientific instrumentation was about $45 million, exclusive of launch and tracking and data acquisition costs.

HEAT MAPPING SATELLITE

Boeing Aerospace Company has fabricated and successfully tested the base module for a satellite which will determine mineral resource locations, sense foliage blight and measure soil moisture effects through the mapping of the Earth's temperature ranges. The module is the premier delivery item for the Goddard Space Flight Center's Heat Capacity Mapping Mission (HCMM) satellite, a spacecraft which will sense the Earth's surface temperatures at the hottest and coolest times of the day.

Knowledge of these temperatures for various segments of the planet will give scientists keys to determine both what is happening on the Earth's surface and what may be located just beneath that surface.

The base module contains the spacecraft's support instrumentation, including receivers, transmitters, power system and attitude control system. After receiving its scientific instruments, the HCMM spacecraft is to be launched in April 1978 from the Western Test Range, California. It will be placed into a 373-mile (600 km) circular, Sun-synchronous orbit and will be known as Applications Explorer Mission A.

The Boeing-built base module is a hexagon about 28 in. (71 cm) across and 25 in. (64 cm) long weighing about 200 lb. (91 kg). It has fixed solar panels with a total area of 24 ft^2 (2.2 m^2).

TETHERED SATELLITES

Fixed priced contracts to conduct parallel definition studies of the Shuttle Tethered Satellite System have been awarded by NASA to Martin Marietta Corporation of Denver, Colorado, and Ball Brothers Research Corporation of Boulder, Colorado. Each study is estimated to cost about $ 290,000.

A satellite of this kind, attached to an orbiting Space Shuttle by a cable up to 100 km (62 miles) long, has several potential applications. Its primary purpose would be to gain scientific data from the Earth's upper atmosphere for global mapping of the Earth's magnetic and gravity fields and studies of atmospheric and plasma physics.

Potential applications for similar tether systems are: cargo transfer between space vehicles; retrieval of satellites or debris without having to manoeuvre the Shuttle; and transfer of large amounts of energy to a remote experiment or from a remote, possibly hazardous, power source to a space station.

MODELBUILDER, specialising in space model kits, wishes to contact others with the same interest, to exchange background information and purchase models not available in Denmark. O. J. KNUDSEN, Hoegh Guldbergs Gade 51 St, DK-8000 Arhus C, Denmark.

BOOK REVIEWS

The Crab Nebula
Eds. R. D. Davies and F. G. Smith, D. Reidel Publishing Company, 1971, pp. 470, $34.50.

In 1054 A.D., Chinese astronomers observed a supernova in the constellation of Taurus. The Crab Nebula is the remnant of that stellar explosion. A bright pulsar, NP0532, lies exactly in the centre of the nebula and is the remnant of the core of the star. The nebula is also a strong source of synchrotron radiation produced by extremely relativistic electrons moving in a magnetic field. The Crab Nebula and NP0532 have been observed over the entire electromagnetic spectrum, from the domain of radio waves to high energy gamma rays. To the best of our knowledge the Crab is unique – there is no other object in our Galaxy like it. The Crab is perhaps the only place where we can observe an obvious connection between the supernova explosion, a neutron star, and the production of high energy particles. For this reason the Crab Nebula was the subject of an I.A.U. Symposium held 5 August 1970. This book is a collection of papers from that Symposium.

The papers are about 60% experiment and 40% theory. Observations of the Crab Nebula and NP0532 are described at radio, optical and X-ray wavelengths and compared with observations of other pulsars and of other supernova remnants. Theoretical articles concern the physics of the Crab Nebula, neutron stars, the radiation mechanism of pulsars, and the connection between the Crab Nebula and NP0532. There is something here about all aspects of research done concerning the Crab Nebula. All basic concepts are covered and the balance is good.

As many of the papers are review articles, the book is a very good introduction to the Crab and to the relevant research up to 1970. Optical and radio observations of the nebula can be taken as "modern" data. X-ray observations of the nebula and of NP0532 have improved greatly since then and better, more extensive, data are abundant in the literature. The study of pulsars has also advanced – the properties of pulsars in general are now compiled from a sample of 140 known objects rather than the 50 known in 1970.

I particularly enjoyed the one page history of the Crab Nebula at the beginning of the book and the optical pictures in an article by Trimble. Maps of polarisation and radio emission are given by Conway and by Wilson. The complete electromagnetic spectrum is reviewed by Baldwin and by Kellogg. The "big picture" concerning the nebula is well done.

This book is recommended as a excellent source of data and ideas about the Crab Nebula. A student of astrophysics could, from this one source, learn the basic observations and theoretical ideas concerning this object. In some areas, however, more modern references must be consulted before undertaking serious research.

PROF. FREDERICK D. SEWARD

Astronomy: The Structure of the Universe
By Wm. J. Kaufmann, III. Collier Macmillan Publishers Limited, 1977, pp. 491, £9.75.

Considering the surfeit of general astronomy books which have appeared in recent years, it is a pleasure to review a book as fresh and authoritative as this. Kaufmann intends his book as a "quality astronomy book for the general astronomy course"; no mean claim, which he admirably succeeds in fulfilling.

Whilst the Solar System is dealt with relatively briefly, the author provides a beautifully coherent text encompassing stellar evolution, white dwarfs, neutron stars, black holes, the Special and General Theories of Relativity, galaxies, quasars and cosmology. It is, not unexpectedly, in the chapters involving relativity that Professor Kaufmann provides a particularly erudite, non-mathematical insight into this most complex and fascinating of subjects. Above all, the author's obvious enthusiasm and jauntiness of style result in rather compelling reading.

The first sections of the book deal with the history of astronomy and with such basic concepts as eclipses, tides and seasons as well as background information on modern telescope systems (*viz.* visible, UV, IR, X-ray and radio). It is interesting to note that the author still refers to the 200" Hale reflector as the largest telescope in the world, with no mention of the Russian 236" telescope on Mt. Semirodniki in the Caucasas (see, for example, *Spaceflight*, Vol. 19, pp. 262-263, 1977); possibly this is because of rumours that the latter instrument's optical performance is not all that it should be. Despite the fact that Kaufmann points out that the Solar System is nowadays the domain of the geologist, meteorologist and engineer, rather than the pure astronomer, he nevertheless provides a concise section on the planets and interplanetary matter, including numerous close-up photographs (some in colour) of Mercury, Venus, Mars and Jupiter.

The latter two-thirds of the book are devoted to remoter and more exotic objects, beginning with the nature and evolution of stars and leading to a discussion on white dwarfs, pulsars and black holes. The chapters incorporating the concept of relativity contain excellent explanations and follow through to its application in helping to understand such phenomena as black holes, and in formulating cosmological models. Whilst often giving the historical background to a particular topic, Kaufmann quickly develops the subject to its most recent state, always giving alternative theories or interpretations where such is the case.

The text is very well illustrated with diagrams and innumerable photographs, together with a number of colour plates. There is a glossary of astronomical terms and an appendix tabulating various data (including the Messier Catalogue). At the back of the book there is a series of simple star charts which may be removed. Altogether eminently readable and highly recommended as a general appraisal of modern astronomy.

S. G. SYKES

Skylab, Our First Space Station
By Leland F. Belew, National Aeronautics and Space Administration, 1977, pp. 169, $7.00.

Credited as having been prepared by the George C. Marshall Space Flight Center, this new member of the NASA SP series provides a splendid overview of the background, development, and successful execution of the Skylab programme. It enjoys a large 29 by 23 cm format, and is profusely illustrated with (mostly colour) photographs taken on the ground, in space, and within the station during its orbital flight. This book does for the first US space station – many prefer to add the adjective embryonic or to use the term "orbital laboratory" – what NASA's *Apollo Expeditions to the Moon* accomplished for the manned lunar programme.

The first two chapters provide a summary of the programme, a description of the four Skylab missions (SL-1 being the station itself and SL-2, -3 and -4 the three ferry flights to it *via* the Saturn 1B carrier), and an historical background. Appropriately entitled "We Can Fix Anything," the third chapter covers the enthralling story of the Saturn 5-boosted Skylab launch and of the troubles that began just 63 sec. into the mission. Few *Spaceflight* readers will forget mission control's horror when the micrometeoroid/heat shield was discovered missing and one of the wing-like solar arrays extending from the body of the orbital workshop module to have been torn off. Complicating matters even further was the recalcitrant second array, for it refused to extend, thereby critically reducing on-board electrical power.

"Tally ho, the Skylab. We got her at 1.5 miles, 29 feet per second," reported Pete Conrad as the first Apollo ferry (command-service module combination) approached the striken station on the 25 May 1973. The chronicle of his, Paul Weitz's and Joe Kerwin's incredible repair operations aloft occupy Chapter 4. The publicity that attended the orbital repair saga helped make Skylab a household word all round the world.

The bulk of the book records the activities of the three separate three-man crews aboard the space station; these activities ranged from routine housekeeping chores to complex astronomical, Earth resources, physical and other scientific and technological observations. Each mission was longer than the preceding one, increasing from 28 to 59 to 84 hours for a total manned time in orbit of just over 171 hours. The astronauts so demonstrated the value of man in space that astronomer Leo Goldberg, director of the Kitt Peak National Observatory was moved to say:

> *Many of us had serious doubts about the scientific usefulness of men in space, especially in a mission which was not designed to take advantage of man's capability to repair and maintain equipment in space. But these men performed near miracles in transforming the mission from near ruin to total perfection. By their rigorous preparation and training and enthusiastic devotion to the scientific goals of the mission, they have proven the value of men in space as true scientific partners in space science research.*

FREDERICK I. ORDWAY

Space Settlements: A Design Study
Eds. R. D. Johnson and C. Holbrow, US Government Printing Office, Washington, D.C. 20402, NASA SP-413, 1977, pp. 185, $5 Paper cover.

This reports a 10 week programme in engineer systems design held at Stanford University and NASA Ames Research Center in 1975, and encompasses a total theoretical overview of future human colonisation of space.

The old line that one can't tell a book by its cover falls by the way side with this volume. The artistry reflects perfectly the total concept, its philosophy and the many questions yet to be answered.

The book, divided into eight chapters with numerous appendices and references, delves into the theoretical as well as practical possibilities of frontier style colonisation of space. To begin, historical references are cited and the design goals for the concept deliniated followed by a description of the basic properties of space, gravitational topography and how it relates to space transportation. It also deals with Solar radiation and its use as an energy source, with matter in space as the materials source for construction, besides describing the problems inherent in ionising radiation and the necessity of overcoming this.

Human needs in space are considered in relation to the major considerations such as i.e. weightlessness *vs* pseudo gravity, the choice of atmospheres, environmental stresses on the population, the size and possible effects of isolation, followed by appendices on psychological and cultural considerations and area and volume requirements for various community activities.

Chapter four asks questions about the space habitat itself; what shape it could take and how the final design, that of a torus,was arrived at. Methods of construction and shielding against radiations, as well as Earth, moon and space resources utilisation are also discussed; all of these are studied in turn in relationship to the various transport systems to be evolved.

There follows a lengthy series of appendices discussing in greater depth the various construction techniques. Industrial concepts and transport concepts such as the lunar gas gun mass driver and the catapult linear indication mass driver, among many others. There is much to whet the researcher's appetite!

One then goes on a tour of the colony, first from Earth to low orbit, then on to the colony itself and its manufacturing facility. From there one travels to the lunar base where ore is mined for the construction materials and one visits the mass driver site where the compacted ore is ejected into space to be caught by a mass catcher for transport back to the colony. This chapter ends with multiple appendices as well, discussing among other things the engineering and designs of this mass driver and catcher, agricultural requirements, types of housing for the colonists within the colony, and the chevron shields which reflect the incident light directly to the colony from a giant primary mirror situated about the colony itself.

Construction methods, energy expenditure, materials and supply, and economic assessments of the whole construction plan are outlined followed by more detailed studies relating to costs, power utilisation and subsystems studies. Possible benefits to both Earth and the colony in research, energy supply, new technologies and resources are described.

The book ends by making several recommendations for research and development and asks many questions addressed directly to the whole concept at large, not least among these being the question, what should the first colony be called? Such questions make the reality of a permanent future in space that much more believable.

The book has many tables, graphs and design drawings in relation to the text and notwithstanding its scientific import, each chapter commences with artist's impressions, so appealing that one feels that he has, indeed, visited the colony!

DR. K. J. O'BRIEN

The Universe
By Josip Kleczek, D. Reidel Publishing Company, 1976, pp. 259. Cloth $27.00, Paper $16.00.

This book is intended for students of astronomy and related fields in physics although I would recommend it for anyone with a basic knowledge of physics and an interest in modern astronomy, for the content lies between that of popular astronomy books and the more restricted texts and review papers. The five main chapters lead through the complexities of elementary particles, to the structures of astronomical objects and their evolution to a consideration of the structure of the Universe.

The first chapter, on elementary particles, gives a general impression of this area in physics and, although quark models are mentioned, the current exciting discoveries are not. The second chapter covers the four basic forces of nature

(gravity, strong and weak interactions and electromagnetic) and discusses how their effects may be detected. The various measured fluxes and their possible origins are mentioned and these include X-rays, light, radio waves, neutrinos and gravitational waves. The third chapter on agglomerates of particles looks at how matter behaves in the many extremes of conditions found in the Universe: the low temperature, low density regime of dust clouds; the high temperature, high density state of the first few seconds of the cosmos found in the hot big bang. The fourth chapter continues this theme by looking at the structures of astronomical objects and ranges from dust through planetary bodies and stars to galaxies and the Universe. The final chapter completes the survey by looking at the evolution of the Universe starting with the big bang, the formation of galaxies and the evolution of stars and galaxies. This is followed by a brief discussion of the origin of planetary systems, evolution of life and Man's place in the Universe.

The main fault of this book is that, although it mentions many interesting areas in astronomy, it does not indicate which areas are still controversial. Sometimes the author, dogmatically, chooses one theory or observation to the exclusion of another equally valid one. Another slightly irritating feature is the complete lack of references to any other works. This makes it very difficult to follow up those areas which catch one's attention. This lack of references contrasts markedly with the very good index provided. Overall, the book provides an interesting glimpse of what is happening in Man's study of the Universe. It should whet one's appetite and encourage further reading.

CHARLES A. WHYTE

Far Infrared Astronomy
By M. Rowan-Robinson, Pergamon Press, 1976, pp. 335, £9.

This book contains the proceedings of a Conference held at Windsor in July 1975, organised by the Royal Astronomical Society. It consists of an introduction, a preface, 36 papers, and indexes. The book is intended primarily for infrared astronomers, though some sections may be of more general interest.

The first chapter describes some of the instruments used in the detection and measurement of infrared radiation, most intended for use from balloon-borne platforms, though mention is made of NASA's Large Space Telescope project. Also described are the constraints forced on the observers by the Earth's atmosphere and atmospheric models to illustrate this are reported. The second chapter describes the results of observations on the Jovian atmosphere and their comparison with some theoretical models. Some of the results of solar atmosphere observations made on the much publicised flight of Concorde during the total solar eclipse in 1973 are reported here.

Results from many groups in a variety of wavelength are recorded in the two chapters on Line Astronomy and Continuum emission. Line observations are limited to molecular lines using radio techniques, due to the lack of detectors in the 20μm to 1 mm region. Most of these observations have been made on H II regions, though some extragalactic sources are mentioned.

The chapter on the cosmic microwave background is particularly interesting. The 2.7 K blackbody radiation, thought to be a remnant of the big bang, has its peak at about 1 mm which is in the far infrared. Observations of this radiation and a measure of its polarisation are reported. Also J. V. Narlikar *et al* suggest an alternative explanation suggesting that the observed radiation is the result of the thermalisation of distant discrete sources by dust grains. They also estimate some constraints on the sizes of these grains. A general discussion completes this chapter.

The final chapter is concerned with theoretical models. Edmunds and Narlikar suggest that interstellar grains may be larger than previously thought and may have a snowflake type shape. This they use to discuss the infrared emission from Seyfert galaxies and quasars. J. Silk discusses the origins and growth of interstellar grains in the protostellar cloud and suggests that such grains are ejected by radiation pressure. A paper by the editor on the structure of optically thick dust clouds and comparison with observed sources is among the longest. The final paper by I. P. Williams suggests that protoplanetary dust clouds may be observable in the infrared. It was noted that observations of R.Mon had been explained by assuming a dust cloud of about the same mass as our planetary system.

The book is fairly technical and, although directly related in the field of infrared astronomy, some of the articles are worth reading on their own and have bearings on other fields.

C. A. WHYTE

Neutron Stars, Black Holes and Binary X-ray Sources
Ed. H. Gursky and R. Ruffini, Reidel Publishing Company, pp. 441, 1976. Cloth $54, Paper $38.

This book is based on a session of the 1974 annual meeting of the American Association for the Advancement of Science, with a view to communicating the recent dramatic advances in the understanding of collapsed objects. It aims to give an up-to-date view of the physics and astrophysics in this field, both from the experimental and theoretical viewpoints.

The book starts with an introduction by Gursky and Ruffini which deals with the history of the subject, the basic theory of gravitational collapse and the discovery of neutron stars and black holes. It traces the development from classical astrophysics through the discovery of white dwarfs to the concepts of much higher-density collapsed objects.

This introduction is followed by an article by Colgate on supernovae, dealing with the explosion process and the formation of a neutron star. Next is a chapter on pulse astronomy by Partridge, which deals with the experimental techniques used to observe the electromagnetic and gravitational phenomena associated with collapsed objects, followed by an article on cosmic gamma-ray bursts by Strong.

The following review of the physics of gravitationally-collapsed objects by Ruffini explains the differences between neutron stars and black holes, besides discussing the problems of observation and differentiation between these classes of object in practice. An article by Kraft later in the book deals with the theoretical aspects of the evolution of black holes and neutron stars in binary systems.

Three articles are devoted to the observation of pulsars (neutron stars), and X-ray sources.

Almost the whole of the latter half of the book is taken up by a collection of reprinted articles. These set the scene which led up to the discovery of gravitationally collapsed objects, starting with seven on the theoretical works on gravitational collapse, and another twelve on the discovery and interpretation of neutron stars and black holes. These articles form the foundations on which the whole subject has been built.

The book provides a well-balanced view of the present state of knowledge on gravitationally collapsed objects. It aims to cater for both the beginner and also the advanced student of the field.

DR. M. D. JONES

The Moon Book – Exploring the Mysteries of the Lunar World
By Bevan M. French, Penquin Books, Harmondsworth, Middlesex and New York, 1977. $4.95.

Since the US Apollo lunar exploration programme was terminated in December 1972, the main focus of interplanetary studies has shifted to the unmanned exploration of the inner worlds Venus and Mercury, the red planet Mars, and Jupiter. The Moon seemed all but forgotten, with only the Soviets occasionally sending a probe to our neighbour in space.

But if Apollo is long over, lunar science is not. In fact, as is emphasized in this well-written and timely book, lunar science is not only holding its own in the wake of Apollo but in many ways is growing. The author, who is programme chief for extraterrestrial materials research at NASA headquarters, estimates that more than 5,000 technical articles have appeared covering Apollo and its fallout during the last decade.

The explosion of knowledge of our satellite began towards noon on 25 July 1969, a mere five days after Apollo 11 astronauts Neil Armstrong and Edwin Aldrin had landed on the Moon. The first rock samples brought back by the explorers were delivered to NASA's Lunar Receiving Laboratory in Houston where a Preliminary Examination of some fifty scientists started their analyses. Less than two months later, the first results of the investigation of the 21.7 kg treasure were revealed during the course of a press conference at NASA headquarters in Washington. Among the principal findings were that the Tranquillity Base rocks are basalts formed from molten lava; that these same lavas flowed on to the surface some 3.7 thousand million years ago; that the lunar bedrock is covered by several metres of broken up and melted rock fragment "soil," and that the surface and subsurface are devoid of present or fossil life forms. Although, during the relatively few years since Apollo 11, mankind has learned more about the Moon than in all the centuries preceding it, the author believes that it will take more than the decade required to achieve the lunar landing to understand everything that was found there.

Following an introductory chapter, French presents what he appropiately calls "The Long Watch," a capsule scientific and science fiction history of the Moon and plans man has engendered to land there. This is followed by a history of telescopic observations of the Moon and of unmanned spacecraft investigations from Ranger to Surveyor to Lunar Orbiter. The manned Apollos 8 and 10 orbital flights are also covered. Then, in Chapter 5, the Apollo 11 saga is reviewed along with the follow-up Apollos 12-17 flights. Chapter 6, the "Anatomy of a Moon Rock," is the heart of the book, describing in turn the scientific tools used by scientists in lunar rock and soil studies, the nature of the rocks brought back by the Apollo expeditions, and a summary of what we have learned.

It is noted that the oldest rocks found on the Moon are dated in the 4.2 to 4.0 thousand million year range, yet, for a number of reasons, astronomers believe the Moon is about 4.6 thousand million years old. As to the reasons for the 500 million year gap, the author writes:

> *Opinions differ on what this gap in the lunar record might mean. One possibility is that with so few Apollo landings we have not be able to find the oldest available lunar rocks. Another possible theory is that the Moon remained molten all through the period between 4.6 and 4.2 billion (thousand million) years ago, so that no solid rocks formed during this period. A third explanation is that the Moon became solid early in its history, but the highlands formed only about 4.2 billion (thousand million) years ago by a major episode of remelting that affected the whole Moon. A final possibility is that the highlands formed very early in the Moon's history but were so shattered and remelted about 4 billion (thousand million) years ago that no older rocks survived.*

Scientists do not yet have the answer, which is one of the reasons why lunar science is such an active field nearly a decade after the first landing at Tranquillity Base.

An entire chapter is devoted to lunar soil, a loose blanket-like deposit overlying the bedrock below. The continuous inflow of cosmic material that creates craters ranging from less than a millimeter to hundreds of kilometers in diameter is the mechanism that manufactures the soil from bedrock. Once formed, this same soil is endlessly reworked and scattered across the lunar surface by the on-going rain of small paritcles. This gives rise to a process known as "gardening." The longer time available for gardening to take place, the thicker one would expect the soil to be. Thus, it was not surprising that the Apollo astronauts found more soil overlying the older highland rocks than over the younger maria.

Later chapters deal with the age determinations of lunar rocks, the interaction of the Moon's surface with solar and cosmic radiation, and the interior of our satellite. Regarding age, though no sample had a "formation age" dating from the creation of the Moon 4.6 billion years ago, there are "rare and tantalizing traces" of such an age in the lunar record. Thus, sample No. 72417 yielded a model age of 4.6 thousand million years, though the author cautions the reader that "the rock itself is so severely shattered and deformed that its history is uncertain, and it is too early to regard it as a piece of the original lunar crust." A footnote, however, refers to later studies of Apollo 17 Sample No. 76535. The results, the author felt, lead one to conclude with some confidence that the mission "*did* succeed in its goal of finding the oldest lunar rocks."

This fascinating book on the Moon ends on an optimistic note for the future. "If this history of our race tells us anything," says the author, "it tells us that where man has once stepped,he will walk again."

FREDERICK I. ORDWAY

The Cosmonauts
By G. R. Hooper, Published Privately by the Author, 1977, pp. 80, £1.00 (UK); £1.25 (Overseas). Duplicated Paperback.

This reproduces the complete collection of biographies of Soviet cosmonauts dealt with by the author in his series of articles which have appeared in *Spaceflight* since February 1975. The information given is correct to May 1977.

Mr. Hooper has listed his potted "biographies in alphabetical order and updated them as far as is possible; he has also included tables on crew assignments, selection dates and a list of cosmonauts in order of their first appearance.

As stated in the introduction this is the first known book of its type to present an up-to-date source on the lives and careers of the Soviet cosmonauts.

The book ends with a section on the 'Unconfirmed Cosmonauts' which appeared as "Cosmonauts-11" in *Spaceflight*, January 1975.

D. J. SHAYLER

Members wishing to undertake Book Reviews for "JBIS" and "Spaceflight" are invited to apply to the Executive Secretary for inclusion in the Society's Panel of Reviewers.

FIRST FLIGHT

By Curtis Peebles

It starts with a long drive through the Southern California night. The hills and towns speed past merging into the high plains of the Mojave desert. In this timeless land, there is a place shaped by the ebb and flow of the seasons into a vast expanse – an expanse as eternal and barren as the crescent moon which glows amid the clouds – becoming the perfect home for the explorers of the sky. Long trails of red tail-lights stretch across the desert to the parking lot.

In the darkness, lights glow; brightest of all is a stark orange tower encompassing the reason for the journey. Tiny figures move about. Slowly dawn banishes the stars. The clouds glow purple and red and so day comes to Edwards Air Force Base. You wait; the cars keep coming in a steady stream. Check the cameras and take a few pictures; focus the binoculars and wait.

Slowly, the 747 and the Space Shuttle "Enterprise" back out of the support tower and move down the taxi way. Two T-38 chase planes wheel overhead; they, too, wait. Slowly, after all the necessary tests are made, the 747/Enterprise moves to the runway.

Crowds gather at every vantage point. They cover the two railroad lines; symbols of another transport system, another time, another frontier. As it sits on the runway, you begin to understand, to believe – it is going to happen. The wait is over now, 8 a.m., a cry of thunder echoes across the base. Slowly, deliberately, the 747/Enterprise moves. Picking up speed, the ties with Earth are broken. Trailed by five chase planes, it enters the sky. Binoculars follow their travels. For almost an hour, final checks are made. Suddenly, all is set; the Sun, the sky, the crowd has assembled and a fledgling is ready to leave the nest. The 747/Enterprise comes around. The countdown begins: "10 minutes, 5 minutes, one minute". Numbers running backwards from infinity to zero. From that moment, long ago, when someone, somehow, knew it would be done.

Thousands of eyes searched for a tiny black speck in the Sun's glare. Mission control wishes them a good flight. The 747/Enterprise begins a gentle descent. As the assembled thousands seek a glimpse, Fred Haise pushes a square white button which detonates the explosive bolts which join the two planes and begins a new age. The radio announces "separation" and applause breaks out. The 747 appears, behind it, a thin contrail. At its peak, almost lost against an immense sky, a white wedge. The contrail disperses and you search again; then a black dot materialises, taking form, becoming larger.

Astronauts Gordon Fullerton (left) and Fred Haise relax on lake bed after the successful first free flight on 12 August 1977.

The men who flew the Space Shuttle Orbiter during its Approach and Landing Tests and the crew of the 747 that launched it pose in front of the Shuttle 'Enterprise'. *Right to left,* Shuttle crew members: Fred W. Haise, Charles G. Fullerton, Richard H. Truly and Joe H. Engle. Boeing 747 crew members are Fitz Fullerton, Victor Horton and Tom McMurtry.

How long had men dreamed of this moment; the oldest most compelling dream – to travel beyond the Earth time and time again? The embodiment of all possible futures, and of man's adventures of the mind and spirit, glides toward the lake bed accompanied by three chase planes. The "Enterprise" is flying free. You watch it remembering forever these brief moments. That familiar shape, the black nose, the high rudder, the shroud covering the rocket engines – so like an airplane yet so much more.

The main wheels touch down raising a cloud of dust. The spectators, scattered across the desert, begin to applaud. The 747 flies over the stopped Shuttle, an eagle saluting the success of its fledgling.

History, as much as technology, went into the Shuttle. All the events, big and little, reeled backwards; events which make up the present and the time to come. The first men challenging the unknown of space; farther back in this same sky, an orange bullet-shaped aircraft called the X-1 became the first to pass the reefs and shoals created by its thunderous passage faster than its own sound and so break the last physiological barrier. And backwards still, to the barn-stormers who introduced wings to a young nation and to the one among them who, in a tiny airplane, would challenge a great ocean – alone. And finally, to two brothers, on a cold December beach, called Kitty Hawk.

Yet only one lifetime separates that beach from the Sun and sky of Edwards. In this brief span has come a profound change; a great shrinking of time and distance. Travels, which once required great danger and hardship, now mean little more than buying a ticket. And even the sky is no longer so infinite; yet with that realisation, came another. Beyond the thin bubble of our atmosphere, there is a great black wilderness which truly is infinite. The essential part of man, which drove him to be one with the eagles, pushes him outward-bound to the stars. The first voyage of "Enterprise" is over and the journey continues.

Spaceflight

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Subject **SPACE TECHNOLOGY**
A twelve week course beginning on **4 January 1978** and dealing with spacecraft orbits, propulsion, structures, power systems, guidance, attitude, tracking and data transmission. **Course Fee: £9.00.**

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Titles **MARTIAN GEOLOGY AS SEEN FROM THE VIKING ORBITERS** by Dr. J. E. Guest.

THE MARTIAN ATMOSPHERE by Dr. G. E. Hunt.
To be held in the Kent Room, Caxton Hall, Caxton Street, London. S.W.1. on **4 January 1978**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Lecture
Title **JUPITER** by Dr. G. E. Hunt.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **1 February 1978**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Lecture
Title **THE OUTER PLANETS** by Dr. G. E. Hunt.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **2 March 1978**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Lecture
Title **MINOR BODIES IN THE SOLAR SYSTEM** by Dr. D. W. Hughes.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **15 March 1978**, 6.30-8.30 p.m.

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CHANGES OF ADDRESS

Notification of new addresses must arrive at the Society's Offices by the 5th of the month if they are to be incorporated in the dispatch list for that month. Requests received afterwards can only be incorporated in the *following* month.

(*NB.* Changes to our records are made on a daily basis, but the preparation of addressing labels for each issue is completed on the 6th of each month and thereafter sent to our Agents for dispatch, so it is no longer available for the incorporated of subsequent changes.)

SPACE EXPLORATION AT THE SCIENCE MUSEUM

Concluded from page 32]

several spacecraft devoted to gamma-ray, X-ray and ultra-violet astronomy have been launched. The actual engineering models of two of these satellites, the European TD1A used for ultra-violet astronomy and the British X-ray astronomy satellite Ariel V, are shown in the section. Some of the experimental packages flown on these successful satellites are also displayed together with solar physics experiments flown on America's OSO satellites and several rocket payloads.

Acknowledgements
We would like to thank the staff of the National Air and Space Museum in Washington, and Mr. F. C. Durant III and Mr. L. Purnell in particular, not only for the loan of priceless space artifacts but also for their encouragement and helpful advice. Our thanks are also due to the European Space Agency, the Science Research Council, the Mullard Space Science Laboratory of University College London, and the Universities of Birmingham, Leicester and Berne for the loan of space hardware.

EVOLUTION OF THE SPACE SHUTTLE

Continued from page 28]

of 270 m. With speed brakes closed up for the approach Haise held off for some 600 m beyond the expected touchdown line and put the main wheels on to runway 17 at a speed slightly in excess of 190 keas; runway 17 is 11 km long and the moderate overshoot was no problem. With main wheels on the ground the speed brakes were brought fully open to the 100% position (90° total angle) setting and the nose wheel slowly rotated to the runway. The flight had lasted just 5 min. 23 sec. and touchdown came 53 min. 51 sec. after takeoff.

The plan then envisaged foresaw second and third free-flight tests on 30 August and 16 September, with a captive-inactive flight in the tail cone-off configuration following shortly thereafter. If it proved feasible to fly the assembly to speed and height levels required for a free flight with the tail cone off an attempt could be made to perform this feat as early as 13 October. Post flight analysis, and a schedule shuffle, moved the second tail cone-on free flight up to 26 August. But heavy rain storms moved in on the Dryden Flight Research Center and the lake bed became water logged, effectively moving the second Phase 3 ALT flight well into September. Nevertheless, the success of the first free-flight drop test was a fitting tribute to the efforts of engineers, technicians and managers in the five long years since Rockwell International received the Shuttle Orbiter contract. Coming as it did in the year that marked the 30th anniversary of Chuck Yeager's first flight through Mach 1 it is a tribute also to three decades of flight research at the Edwards Air Force Base.

[To be continued

SPACEFLIGHT

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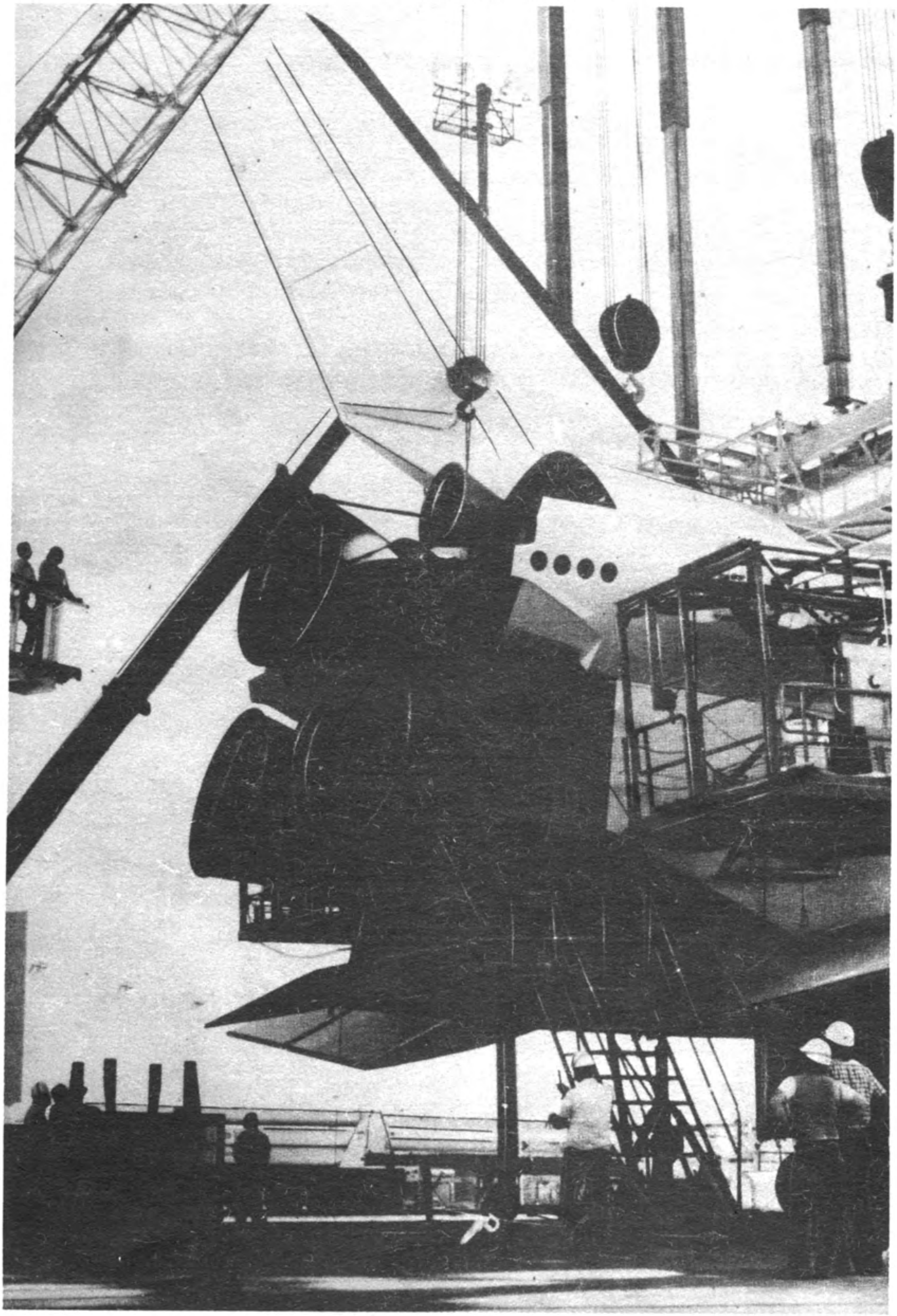

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Assistant Editor:
L. J. Carter, ACIS, FBIS

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COVER

HUNTSVILLE SHUTTLE. Next month the Space Shuttle 'Enterprise' will be air-lifted on its Boeing 747 'mother' to the Marshall Space Flight Center in Huntsville, Alabama. There it will be installed in a tall tower where tests will check out the ability of the Orbiter, External Tank and Solid Rocket Boosters to maintain proper guidance and control under vibration conditions expected to be encountered during launch and powered flight. Picture shows the tail end of 'Enterprise' with dummy rocket engines installed.

National Aeronautics and Space Administration

Cover design by David Holmes

SPACEFLIGHT

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VOLUME 20 NO. 2 FEBRUARY 1978 *Published 25 January 1978*

MILESTONES

November

14 NASA and Soviet Academy of Sciences begin three-days of discussions in Moscow on further collaboration in space. Two working groups are set up "to define scientific areas for possible experimentation which might benefit from the flexible delivery capability of the NASA Space Shuttle and the capability for longer stay time in orbit represented by the Salyut space station."

14 Researchers from Lawrence Berkley Laboratory and University of California, Berkley, obtain measurements of cosmic microwave background from high-flying U-2 aircraft which suggest that the Cosmos may have originated "with a powerful but tightly controlled and completely uniform expansion." not a 'Big Bang.'

15 First of four ferry test flights of the Space Shuttle *Enterprise*, mated to the Boeing 747 'mother,' at Dryden Flight Research Center measures performance of the combination with a three degree forward angle between them. Previous flights were flown with a six degree angle. Data gathered will be used for planning first ferry flight – now scheduled for March 1978 – when *Enterprise* will be transferred by the 747 to Marshall Space Flight Center in Huntsville, Alabama, for ground vibration tests.

16 European Space Agency reports that the new Soviet geo-stationary weather satellite, designed to contribute to the World Weather Watch and Global Atmospheric Research programmes of the World Meteorological Organisation (WMO), will not be ready in time for the experiment which begins at the end of 1978. It was expected to join Meteosat, two American satellites and one Japanese (see *Spaceflight* October 1977, p. 349). The WMO is studying alternative possibilities.

21 Next launch of an Atlas-Centaur rocket from Kennedy Space Center is rescheduled for "no earlier than 6 January 1978" because of discovery of "some faulty feed-back transducers used in the Atlas actuators for engine control" which are being replaced. Launch of an Intelsat 4A communications satellite, originally scheduled for November 1977, was first delayed by investigation into failure of the previous Atlas-Centaur on 29 September.

22 Martin Marietta Corporation of Denver, Colorado, is awarded a $1.735 million contract for conducting all analysis and design activities necessary to support a Teleoperator Retrieval System (TRS) Preliminary Design Review in early March 1978. The Teleoperator Retrieval System – a retrievable, re-usable, low thrust stage – will be used to survey, stabilise, and manoeuvre payloads in low Earth orbits and will be used in conjunction with the NASA Space Shuttle in the early 1980's. NASA's Marshall Space Flight Center has been assigned management responsibility for TRS development.

23 NASA launches ESA Meteosat 1 from Cape Canaveral by Delta 2914 rocket at 0135 GMT (see page 48). Launching had been delayed nearly three weeks by a succession of problems: investigation into the loss of the OTS Delta 3914 on 13 September; a leaking valve in the second stage of the Delta 2914, and unidentified radio signals in the same radio frequency range as the rocket's emergency 'destruct' system – traced to a ship in the Cape Kennedy area. At approximately 1600 GMT Meteosat 1 is transferred from initial orbit to geo-stationary orbit by firing the on-board apogee boost motor. Satellite "is now moving towards its station over the equator on the Greenwich meridian at an altitude of approximately 35,800 km," reports Marconi Space and Defence Systems, the company which provided the satellite's attitude and orbital control systems.

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ARIEL 5: A BRITISH TRIUMPH

By Dr. Malcolm J. Coe*

Introduction

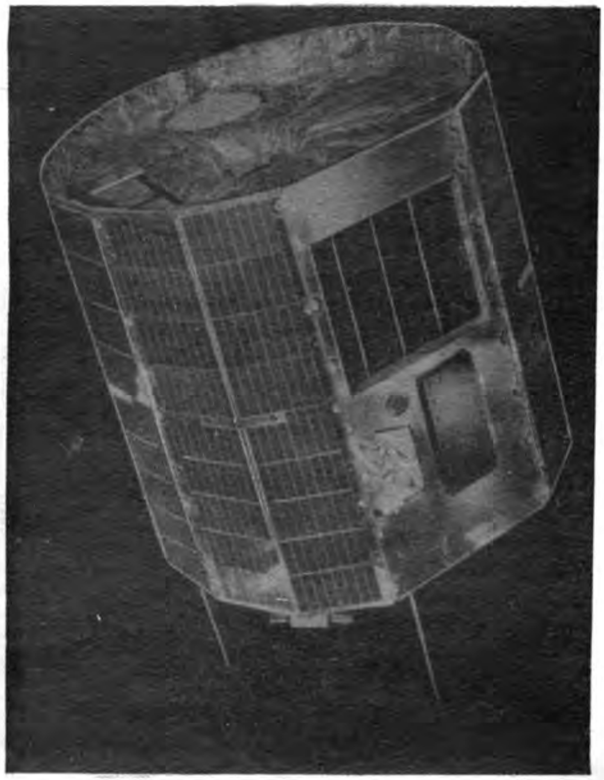
X-ray astronomy was born somewhat serendipitously at midnight of the 12 June 1962 some 200 km above the New Mexico desert. A small Geiger counter built at the Massachusetts Institute of Technology sitting on top of a US Air Force Aerobee 150 rocket glimpsed for the first time the powerful X-ray source Scorpius X-1. This result surprised the scientific community when R. Giacconi and his colleagues announced their results in the early Autumn, because any possible source of stellar X-rays – other than our own Sun – was generally believed to be totally undetectable. Indeed, the purpose of the rocket experiment was merely to see if the Sun caused the Moon to fluoresce in X-ray light. The implications were amazing. It meant that if the source was a nearby star, let alone – and much more probably – a distant one, the source had to be at least 10 million times more powerful an X-ray source than our Sun. The energy mechanisms involved needed to be colossal. Such an object was totally unsuspected and it was a dramatic introduction of the new member to the family of Astronomy.

Over the next 7-8 years many rocket flights followed in the path of this first one and painfully slowly an X-ray picture of the sky began to emerge. This picture was one of several bright point-like objects superimposed on a general diffuse background of X-rays. The whole sky seemed to glow in these isotropic X-rays, the origin of which is still far from certain. Despite this intriguing aspect, the main interest was directed at pin-pointing the distinct sources and linking them with previously known astronomical objects. By the late 1960's two such identifications had been carried out: firstly, the brightest source Scorpius X-1 had been identified with a rather unusual optical star; and secondly, the ever-present Cran Nebula, known already to be an optical, radio and infra-red source, was established also as an X-ray source.

Progress, however, was slow. Each rocket flight provided a mere 5-minute glimpse at the sky at best. Instruments carried above the bulk of the atmosphere by balloons did somewhat better, perhaps observing for an hour or two, but they could not really get high enough to allow the more intense, softer, X-ray flux to reach the instruments. It was becoming obvious that the only practical solution lay with satellites. Thus, in the late '60s, two satellite projects were conceived. Firstly, the Americans decided to dedicate a satellite purely to X-ray astronomy. This was to be the first of the Small Astronomical Satellite series and it was successfully launched in December 1970 from a converted oil-rig off the coast of Kenya. This site was chosen because it was desirable for scientific reasons to place the satellite in an equatorial orbit and the easiest way to do this is to launch from the Equator. Because of its connections with Kenya the satellite was named "Uhuru" – the Swahili word for freedom.

A few years later in October 1974 Uhuru was followed into orbit by the British satellite Ariel 5. Similarly dedicated to X-ray astronomy, and similarly launched from Kenya, this satellite was fifth in the joint UK/NASA space exploration programme. Basically the Americans provided the launch vehicle (a four-stage, solid-fuel Scout rocket) and the British built the satellite. It was to continue from where the by-now defunct Uhuru had left off and put British astronomy once more into the front-line of research.

* *The author is an X-ray astronomer working at the Blackett Laboratory, Imperial College of Science and Technology, London.*



The Ariel 5 satellite. Solar panels cover most of the external surface. The scanning experiments are on the side and the pointing experiments on top.

Photo: Appleton Laboratory

Observational Techniques

To help understand X-ray astronomy in general and Ariel 5 in particular we must first know how this science is practised. X-rays are high energy (short wavelength) electromagnetic radiation and these photons are capable of deep penetration into matter. The energy of an X-ray is usually measured in kilo electron volts (keV), where one electron volt is defined as the energy imparted to an electron accelerated across a potential of one volt. It is also approximately equal to the amount of energy someone of the Earth would receive per second from a 100 watt light bulb sited on the Moon!. So the problem is to find techniques that can stop these X-ray photons and measure their energy. This is done in two ways. Firstly, for the weaker (or 'softer' in the jargon of X-ray astronomy) X-rays we can trap a suitable high density gas such as argon or krypton in a chamber and rely on the X-ray bouncing around off the gas atoms until it has lost all its energy. This can then be measured from the amount of ionization it has caused in the gas. Such a device is called a proportional counter because the amount of ionization measured is directly proportional to the energy of the X-ray. These devices are used in the range 1 keV to 50 keV. To measure the more powerful, or 'harder', X-rays we must consider a second technique. At energies above 50 keV we find that our gas box cannot stop the X-ray before it escapes out the other side, so we need to increase the density of the atoms in our box to make it even more

difficult for the photon to find a way out. In fact we use a solid; normally a crystal. This is usually one of the crystal solids Csi or Na I (very similar in structure to common salt, NaCl) which have the property of producing little flashes of light, or scintillations, corresponding in number to the energy of the incoming X-ray. These scintillations are counted using a light sensitive photo multiplier. Unfortunately such crystal scintillators are rather expensive (the scintillator/material costs about its own weight in gold) and for the hard X-ray instrument on Ariel 5 about 10 lb. (4.53 kg) of scintillator were required. Luckily, it is in a fairly safe place.

Having measured the energies of these incoming X-ray photons we then plot a graph of the number of photons against their energy. This is called a spectrum and, in general, we find that it reveals that most cosmic X-ray sources produce far fewer X-rays at high energies than at weaker energies.

Ariel 5

The Ariel 5 satellite consists of a cylinder of approximately 1 metre diameter and similar length. It weighs about 300 lb. (136 kg) and was built by Marconi Space and Defence Systems Limited in Portsmouth, England. Most of the sides of the cylinder are covered with solar panels which provide the power for the spacecraft while in sunlight. During eclipse periods the experiments are switched off but the core stores and data handling facilities are kept operable with the aid of a rechargable battery. It was launched into a 545 x 500 km orbit inclined at 2.9° to the equator with a period of 95 minutes. Thus, since data from the experiments are acquired for about 60% of the time, about one hour's observation per orbit is obtained.

Every orbit the contents of the core stores are dumped to either of the NASA ground stations at Quito in Ecuador or Ascension Island. From there the data goes *via* the Goddard Space Flight Center, Washington, to the UK control centre at the Appleton Laboratory, Slough. All the satellite operations are controlled from here and the incoming data distributed by GPO telephone lines to the various participating British Universities. The System is so fast and efficient as to enable astronomers to have results from their instrument within two hours of observation, thereby permitting a quick response to new phenomena.

The set of six experiments on board are intended to be complementary, covering all the various aspects of X-ray astronomy. They fall into two groups. Firstly, there are the "pointing" instruments which are aligned with satellite spin axis and, secondly, there are the "scanning" experiments which point orthogonally to this axis. The first set consists of the following four experiments.

(a) the high energy scintillation telescope supplied by Imperial College, London University, measuring spectra in the photon energy range 30 keV to 1,000 keV;

(b) the low energy proportional counter supplied by University College, London University, covering the spectral energy range 2 keV to 30 keV;

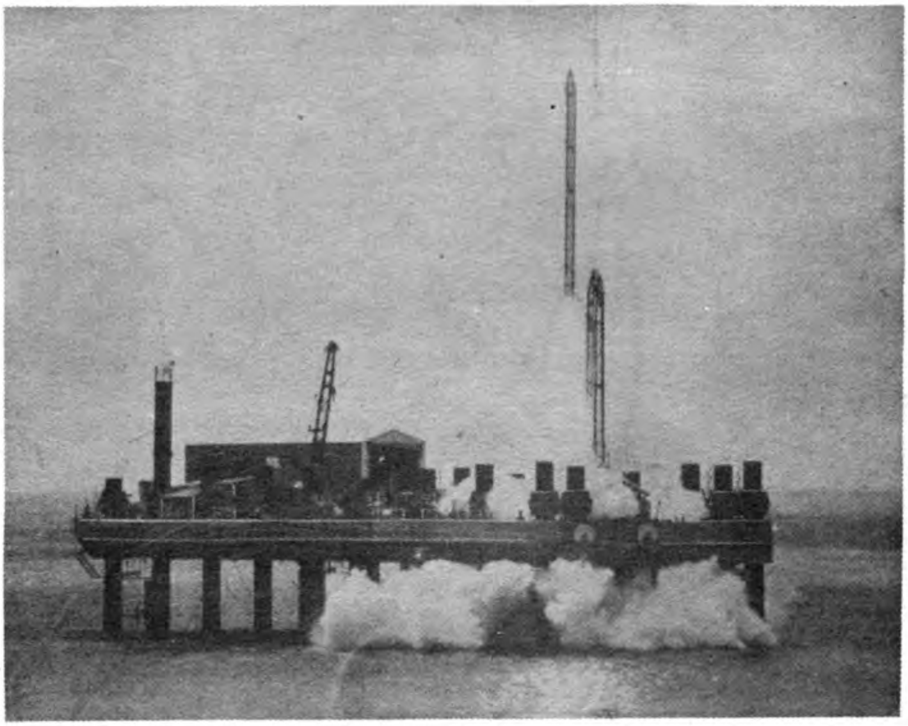
(c) the proportional counter operated by Birmingham University which locates the positions of sources emitting X-rays in the 3-9 keV band;

(d) the Bragg spectrometer supplied by Leicester University which looks for X-rays of discrete energy values which could have come from particular elements in stars (such as iron).

The remaining pair of experiments are located in the side of the spacecraft and are:

(a) a set of two proportional counters also supplied by Leicester University which scan a narrow strip of sky around the satellite's equator as it rotates. They cover the energy range 2-20 keV;

(b) an all sky monitor provided by experimenters at NASA's Goddard Space Flight Center which con-



Ariel 5 lifts off from the San Marco platform offshore of Kenya on 14 October 1974.

Photo: A. R. Engel

stantly watches nearly all the sky, but with much poorer time resolution than the other scanning experiment (one hour rather than a few seconds).

The satellite until recently was manoeuvred by means of propane gas jets located around the lower rim of the cylinder. At the time of writing (August 1977) the gas supply has just been exhausted so now the back-up "magneto-torquer" is being used. This device simply consists of a coil of wire wrapped around the satellite which is energised with a current and the resulting magnetic field interacts with the Earth's magnetic field to produce a torque or twisting motion on the satellite. At any time the orientation of the satellite may be determined using various Sun-sensors located on the satellite's side at different angles to each other.

To date, the satellite has completed about 16,000 orbits – a colossal distance of 450 million miles (724 million km) – and at a much lower cost per mile (only 1½ pence) than most cars on the road today.

The Scientific Yield

The results of Ariel 5 have led to about 100 papers being presented to date in leading scientific journals and at meetings. This astounding outpouring reflects the significant advance of the Ariel 5 satellite over Uhuru as an X-ray observatory. For the first time X-ray objects were being studied over long time intervals and over wide energy ranges with the result that the true complexity of the sources began to emerge. As compared to other branches of astronomy, the X-ray sky is an extremely active and volatile one. Sources have been seen to bang, flare, flicker, oscillate, get hotter or colder, disappear or appear – but rarely remain constant. The only notable exception is the Crab Nebula, X-ray astronomy's answer to the "northern star." Only a few of these manifold characteristics can be considered here.

(a) *Transient X-ray sources.* These are a class of objects which exist as X-ray emitters for only short periods ranging from the extremes of a few hours to a few months. During this period they generally are characterised by a dramatic appearance, often rising so high in intensity that they become one of the brightest X-ray sources in the sky, and then a gradual decline back into obscurity.

Prior to the launch of Ariel 5 only a handful of such sources were known and the possibility of instrumental effects often led to suspicions about their existsnce. It was predicted that Ariel 5 might see one such flaring source per year but instead the number is closer to ten times that. In addition these sources have provided some of the most intriguing results yet to come from the satellite.

The transient in the constellation of Taurus provides us with a good example of such an object. This source exploded into life in mid-April 1975 right in front of the array of pointing instruments – an extremely fortunate event needless to say. Within a few days it was outshining its famous neighbour in the sky, the Crab Nebula, and by May Day it was by far the brightest hard X-ray source in the cosmic sky. In the first 20 days of its life it radiated more energy than our Sun does in 200 years.

In addition to its power, the X-ray emission was observed to be modulated with a period of 104 seconds. This is understood to be the rotation period of the source, probably a collapsed dwarf star as it is spinning so fast. The radiation is believed to come from the magnetic pole which, like on the Earth, is offset from the star's spin axis. Thus as the pole spins around it beams X-rays outwards in a manner analogous to a lighthouse. This dwarf star was later shown also to have a 17-day periodicity representing the binary rotation of it around an enormous, optically-variable star. From combined spectral measurements made by the Imperial College and Birmingham University instruments the temperature near this compact star was estimated to be about 100 Million °K (this may be compared with 1-2 million °K in the hottest parts of our own Sun). Exactly why the Taurus nova suddenly came into existence is still unknown but it certainly made its mark in the sky.

Ariel 5 control centre at the SRC Appleton Laboratory, Slough. From here all the manoeuvres and data management are carried out.

Photo: Appleton Laboratory

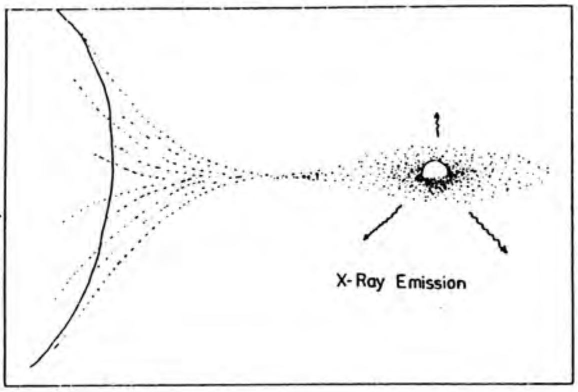


Fig. 1. The popular model for cosmic X-ray production incorporating a binary system. The matter boils off a large, optically-visible star and falls into the gravitational well of a compact object such as a neutron star, white dwarf or black hole. Because of the star's rotation an accretion disc is formed by the infalling material, and it is during its passage through this disc that the loss of gravitational energy is converted into X-rays.

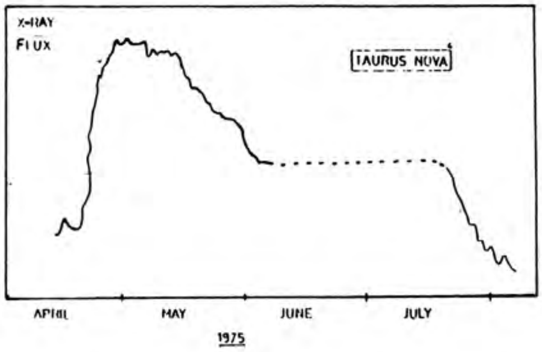


Fig. 2. The light curve of the X-ray nova Tau X-T. The sharp rise and gradual decay is clearly seen. This is found to be typical of such X-ray transients. Data from the Birmingham and Leicester experiments on Ariel 5.

(b) *Well-established sources.* These number about 100-200, some of them having been around since the beginning of X-ray astronomy. They are generally always there when one looks for them, though their intensity may easily vary by factors of ten. Some, like the Crab Nebula, are so steady that they are accepted as good standards to calibrate one's instruments by. Others are still revealing interesting new aspects. These objects have represented the bread and butter of Ariel 5's work and have probably led to at least half the published papers.

One such subject is in the constellation of Hercules and is known ar Her X-1. It is a complicated system involving a spinning neutron star, and possibly involving a third as-yet unknown object. For three weeks in every month the source mysteriously disappears from sight – hence a possible need for a third body to hide the system during this period. During observations in February 1977 the Imperial College experiment observed a strange "bump" in the spectrum which may for the first time give us a direct insight into neutron stars. This "bump" is thought to arise from the presence of an extremely strong magnetic field in the star and by measuring the position of it in the spectrum the strength of the magnetic field may be estimated. This is thought to give for an answer a field strength a million, million times stronger than that of the Earth's. So we have a star of density 100 million, million times that of lead spinning once a second in this colossal magnetic field bombarding the Universe with a powerful beam of X-rays. Science fiction has a long way to go to catch up with fact!

Another example of a well-established X-ray source is the Perseus cluster. This is a cluster of galaxies (not stars, but galaxies each containing millions of stars) of enormous size at a distance of 100 mega-parsecs. There is generally X-ray emission from the whole of the cluster with a concentration centred on one particularly active galaxy – NGC 1275. The Cluster as a whole subtends one degree at the Earth (i.e. twice that of the Moon) and it is from this overall region that the University College experiment has observed a spectrum which also contains an interesting bump.

This feature at only one-tenth of the energy of the Her X-1 bump has a totally different interpretation attached to it. It is believed to be produced by iron in the cluster at a very hot temperature (about 10 million degrees). This is the first time this effect has been observed from Perseus and it enables us to calculate from its brightness the amount of iron present there. This then gives us a powerful tool to test the many cosmological theories of the Universe as they all need to explain the distribution of matter. In this case the amount of iron computed is in reasonable agreement with the generally accepted cosmic abundance of this element as, for example, measured in our own Sun. Thus our understanding of the evolution of the Universe is taken one step further.

(c) *X-ray bursts.* The discovery in the last few years of sources that produce powerful bursts of X-rays has caused great excitement. These outbursts typically last only 10-20 seconds and sometimes come in trains of pulses.

There are now about 15 sources known to exhibit this phenomenon with one particular one near the Galactic Centre being extremely active. Known as the "Rapid Burster" it has periods of activity lasting a month or so during which it is constantly producing enormous bursts. The interesting aspect about these bursts is that the bigger they are the longer it is until the next one appears, as if the source takes longer to be replenished.

Ariel 5 experiments were pointed at this source in April 1976 soon after its discovery and several new properties were uncovered. Firstly, the Birmingam experiment established that the source has a steady signal associated with its emission so that the net result is rather analogous to a modulated radio transmission. Secondly, by co-ordinating the Imperial College hard X-ray observations with the softer ones of the University College experiment, it was noted that there was a delay between them. First of all the soft flux arrived and then about 30 seconds later the hard X-ray burst was seen. Using all these facts the theoreticians now believe that what we are seeing is an extremely unstable variation of a standard X-ray emitter, with the exotic possibility that a black hole a million times bigger than normal may be involved. Whatever the true cause of these outbursts, there is no doubt that they represent the most violent behaviour yet observed in the Universe, natural or otherwise.

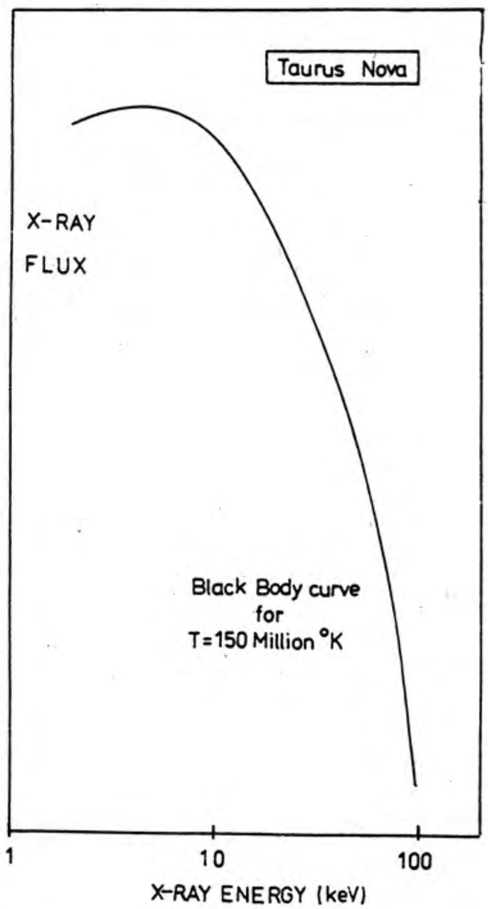


Fig. 3. The X-ray spectrum of Tau X-T which indicates that temperature of 150 million degrees in the nova were causing the X-ray production. Data from the Imperial College and Birmingham University experiments on Ariel 5.

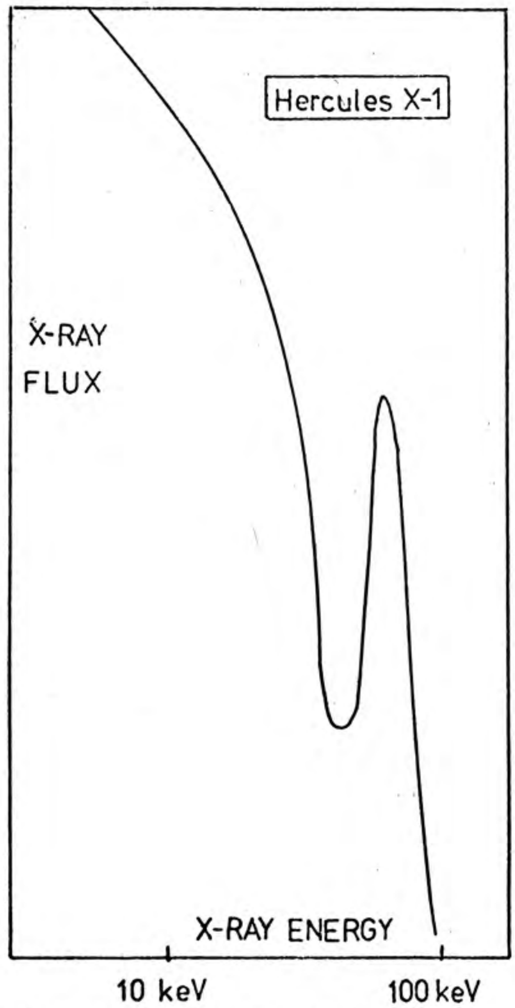


Fig. 4. The X-ray spectrum of the complex X-ray source Hercules X-1. The line feature shown at 60 keV is believed to be due to the presence of an extremely strong magnetic field on the neutron star in the binary (or possibly tertiary) system. Data from the Imperial College experiments on Ariel 5.

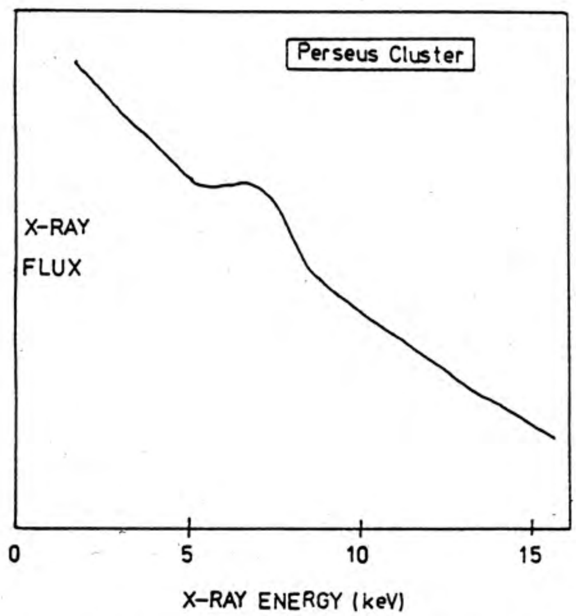


Fig. 5. The X-ray spectrum of the cluster of galaxies in the constellation of Perseus. The bump at 7 keV is thought to be caused by ionized iron and the size of the bump enables the amount of iron to be calculated. Data from the University College experiment on Ariel 5.

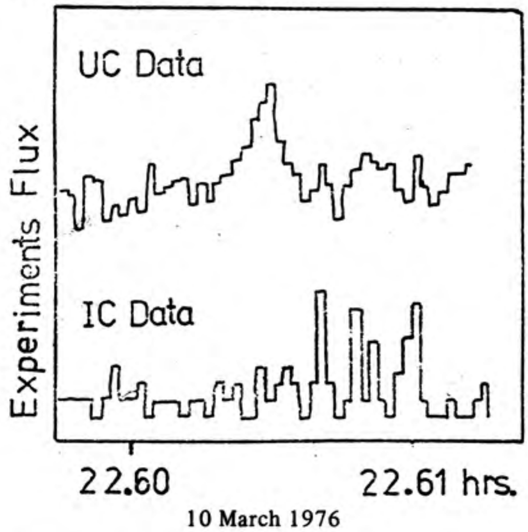


Fig. 6. The time profiles of an X-ray burst from a source near the Galactic Centre. The delay between the University College (UC) data in soft X-rays and the Imperial College (IC) data in hard X-rays is believed to be real and may provide a vital clue in understanding the production mechanism.

The Future

The Ariel 5 satellite is now past its prime and will probably finish its operations around late 1978 to fit in with launch of Ariel 6. The next generation of X-ray satellite – HEAO A (see *Spaceflight*, July 1977. p. 271) – was successfully launched in August 1977 should be able to do most of the tasks Ariel 5 has been doing, but much better. Up till its switch-off date Ariel 5 will adopt a more sedate role (as befits a satellite of its age and prestige) and slowly scan the sky covering most of the interesting sources for a final time. While it would be extremely unwise to preclude a new phenomenon in X-ray astronomy occurring, the ability of Ariel 5 to participate is now limited by the lack of propane gas. So any such event would have to occur within the area of sky currently being observed.

Nonetheless, this last year will enable the astronomers operating Ariel 5 to consolidate their data and hopefully tie up some of the many loose ends these hectic three years have left. Catalogues of the sky will be completed and published for future X-ray observers, detailed long-term studies of many sources will be produced – in most cases for the first time – and the final batch of new transient sources added to the collection.

There can be little doubt that measured in terms of scientific discoveries and the prestige of our science, Britain has done extremely well for its investment. Let us hope that its support of Space research and exploration will continue in the future and that it will pay off as well as it has done with Ariel 5.

Acknowledgements

The author would like to thank the many scientists whose work he has used in this article. There are too many to list individually and he hopes that no one will be offended by the absence of their names. Furthermore, much credit must go to the Appleton Laboratory for their excellent data management and, of course, to the Science Research Council for funding the whole project.

MILESTONES

Continued from page 41]

November

25 BIS announces *via* Press Association and Reuters completion of the Daedalus star probe study coincident with publication of Summary Report in the December issue of *Spaceflight*. (Full Report will be published in mid-1978 as a Special Supplement of *JBIS*).

25 *Novosti* reports that an ultra-powerful single-cylinder press "capable of exerting a pressure of millions of atmospheres" has been installed and tested at Troitsk, near Moscow. The test pressure in the working chamber reached 1,200 kg/cm^2. "Such multi-stage high-pressure chambers, designed after the pattern of the Russian matryoshka doll (in which one doll fits inside another in diminishing sizes)" make it possible to study substances such as metallic hydrogen (see *Spaceflight* May 1977 p. 175). The press was built for the USSR Institute of High Pressure Physics by a factory at Kramarorsk in the Ukraine.

27 *Novosti* reports that first section of world's largest underground neutrino telescope "has gone into permanent service" in the Caucasus. Sited a third of a mile underground in the foothills of a mountain, initially the telescope will be used to investigate neutrinos from the Sun (see "Exploring the Neutrino Universe,' *Spaceflight* July-August 1976, and 'Soviet Neutrino Astronomy,' *Spaceflight* 1977).

28 Orbit of Salyut 6 space station is changed to 345 x 360 km x 51.6 deg to equator; period 91.4 min. All systems are functioning normally.

29 Salyut 6 completes 968 revolutions of the Earth at 1500 hr. (Moscow time).

30 Scientists in Moscow announce preliminary results of Cosmos 936 bio-satellite experiments "to study ways of protecting living organisms from the effects of prolonged space flight." it was found that artificial gravity had "a beneficial effect on higher living organisms. Rats aboard Cosmos 936 which lived under weightless conditions underwent a number of functional changes. Such changes were less distinctive or entirely absent from those rats kept in two centrifuges during the flight." Good results were also obtained "in investigating ways of protecting organisms from charged particles in outer space and in the dosimetry and spectrometry of space radiation."

30 Boeing Aerospace Company receives SAMSO contract for integrating the Interim Upper Stage (IUS) with satellite payloads destined for orbits unattainable by their primary launch vehicles. Boeing is already prime contractor for the IUS family of space boosters which will serve as higher orbit delivery vehicles both for the NASA Space Shuttle and the DoD Titan III rocket. First IUS launch is scheduled for mid-1980 from the Space Shuttle Orbiter. It will transfer a Tracking and Data Relay Satellite from the Orbiter's 150 n. mile orbit to geostationary orbit.

30 Choice of ESA Spacelab payload specialist candidates is narrowed from 54 to 11. Selection includes one UK representative, Keith O. Mason, Ph.D. (26), who joins two Germans, an Italian, a Belgian and the only woman, Mme Anny-Chantal Levasseur-Regoud, 32, a physics lecturer at the University of Paris. The other five candidates will be selected in the United States. Although only one European is required for the 1980 flight, there will be two back-ups. It is hoped that others will find a place on later missions.

SPACE REPORT

A regular monthly review of
Space Events and Technical Trends

EUROPE'S WEATHER SATELLITE

As we go to press Europe's first weather satellite, 'Meteosat,' is taking up station in geostationary orbit some 22,300 miles (35,880 km) above the Gulf of Guinea at longitude 0°. It is expected to give total and continuous weather coverage of Europe, the near East and Africa for at least three years.

The 697 kg satellite was launched by a Delta 2914 rocket from the Eastern Test Range, Cape Canaveral, Florida on 23 November 1977 at 0135 GMT.

Although Meteosat has been designed to meet the European meteorological services' own requirements for more accurate long-range weather forecasting, it will also make a contribution to two programmes set up by the World Meteorological Organisation (WMO), namely the World Weather Watch – a continuous programme – and the Global Atmospheric Research Programme (GARP) in which the first experiment is due from the end of 1978 to the end of 1979.

Within these programmes, Meteosat will be one of the links in a world chain of five geostationary satellites comprising the European satellite, two American satellites, one Soviet satellite and one Japanese satellite (see diagram *Spaceflight,* October 1977 p. 349).

Meteosat has three main objectives:

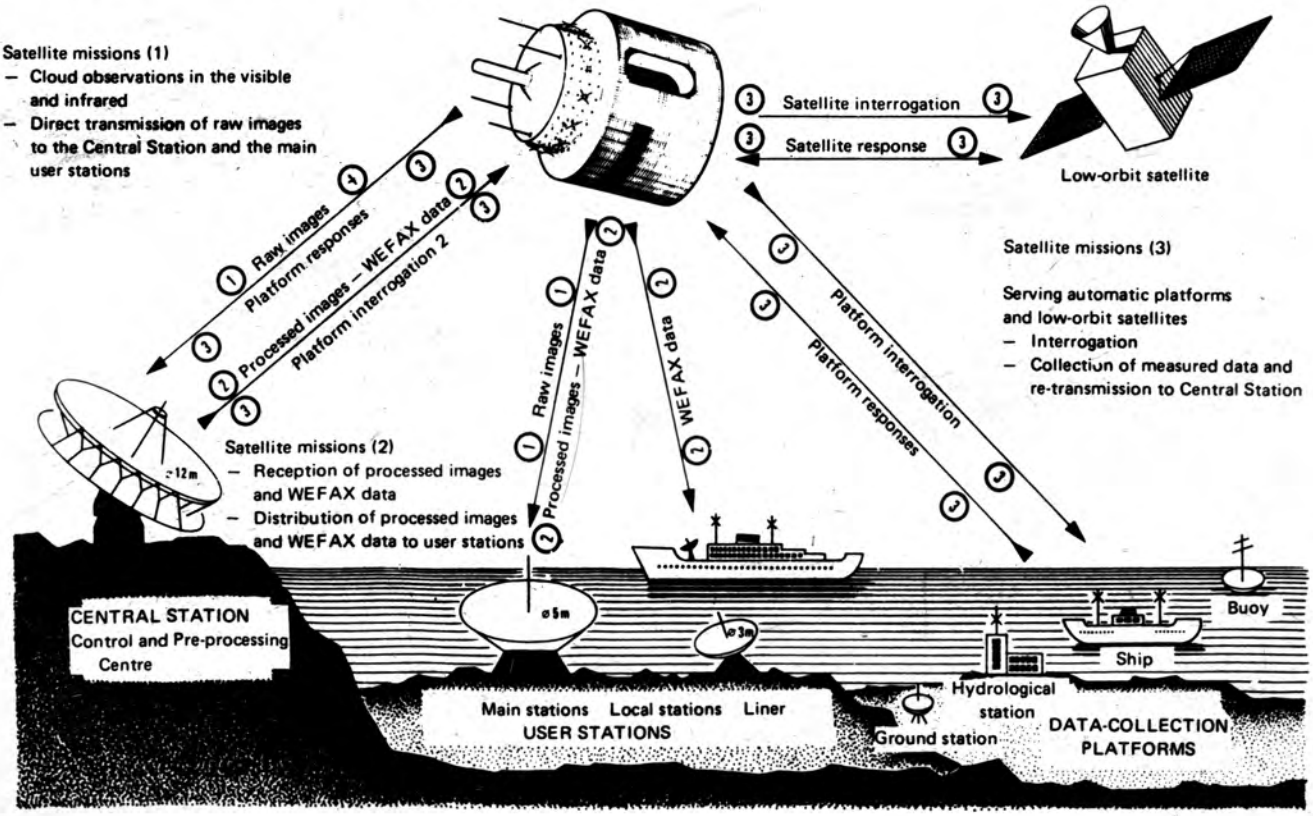
- *Earth-surface and cloud-cover scanning every half hour, simultaneously in the visible and infrared regions of the spectrum.*
- *Dissemination to the users – meteorologists, oceanographers, hydrologists, etc. – of the pictures and meteorological data derived from the radiometer images, namely, Earth-surface and cloud-top temperatures, wind fields, radiation balances and meteorological charts.*
- *Collection of environmental data obtained locally either by automatic and semi-automatic stations or by a satellite in a low polar orbit.*

The launch vehicle placed the satellite on a very extended elliptical orbit with perigee at 185 km and apogee at 37,000 km and spun it up to 100 revolutions per minute. After separation of the satellite from the third stage, the European Space Operations Centre (ESOC) at Darmstadt in Germany, acting through the San Marco station in Kenya, ordered the necessary corrections to orient the satellite spin axis in the optimum direction for the firing of the apogee motor. This operation, which took place some 14 hours after launch, brought the satellite to its drift and positioning orbit.

On this new path the satellite drifted slowly Westward for three weeks, moving over the Indian Ocean and Central Africa until it reached its final position above the Gulf of Guinea. During this latter phase, further stabilisation manoeuvres were being carried out to place the satellite in its operational station, the radiometer and the beam of the high-gain antenna being directed towards the Earth. Meteosat then was being linked with the Michelstadt station ready to begin its mission.

The overall Meteosat mission, illustrating the types of data transmitted to and from the satellite.

European Space Agency



VALENTINA RETURNS

Valentina-Nikolayeva-Tereshkova, the world's first space woman, visited London in October to attend celebrations marking the 60th anniversary of the Bolshevik Revolution. She gave a press conference at the Soviet Embassy and was greeted, on behalf of the British Interplanetary Society, by Kenneth Gatland who was a member of the reception committee during her first visit to London in 1964 to receive the BIS Gold Medal to mark her historic achievement.

Valentina Tereshkova circled the Earth 48 times in Vostok 6 on 16-19 June 1963. After the flight she married Andrian Nikolayev and had a baby, Yelena, now 13 years old. The family live in Star City, near Moscow, the cosmonauts' training centre.

Asked if she would like to go into space again, Valentina replied that anyone who had been in space would wish to repeat the experience to build upon the impressions gained. Did she now regard herself more as a diplomat than a cosmonaut? Unhesitatingly she replied that space flight was her profession. However, at present "there are no plans for training women for any specific flight, but there was no reason why women should not take part in flights on a equal basis with men."

What had happened to her two backups who had trained for space flight in the 'Sixties? Valentina replied that they were both working at the Gagarin Cosmonaut Training Centre. They were now engineers – "very good engineers, and good mothers, too!" Many people working in the Soviet space programme were women including designers, engineers, medical specialists, etc.

Asked if her cosmonaut husband Major-General Nikolayev and child were still under regular medical observation because of possible genetic effects of radiation in space, Valentina said Soviet space flights were timed so that they avoided those periods when the Sun's radiation was most intense. The radiation dosage received by Soviet cosmonauts was less than that produced by a chest X-ray. All cosmonauts, however, were under strict medical control and observation. Her daughter, being a child of two cosmonauts, was "just like any other young girl."

On the subject of space collaboration, Valentina said everyone would benefit if the Soviet Union and Britain worked together on space projects. She recalled Soviet-US cooperation in the Apollo-Soyuz Test Project and pointed out that the Soviet Union was also cooperating in the space field with France, India and Sweden, as well as with socialist countries. "If Great Britain joined them, it would be of universal benefit," she continued.

Valentina Tereshkova graduated as an aeronautical engineer from the Zhukovsky Air Force Engineering Academy in 1969 which she had entered five years earlier.

In 1967 she was elected member of Parliament (Supreme Soviet) for her home constituency of Yaroslavl and to the Presidium of the Supreme Soviet in 1974.

Valentina Nikolayeva-Tereshkova in London 31 October 1977.

Novosti Press Agency

SIXTH PROGNOZ

On 22 September 1977, at 3:51 a.m. (Moscow time) the Soviet Union launched the automatic station Prognoz 6 by an A-2-e rocket from the Tyuratam cosmodrome, writes David J. Shayler. The Prognoz (Forecast) series, begun in April 1972, has the objective of monitoring the Sun and solar phenomena from terrestrial orbits (*Spaceflight*, May 1977, p. 174).

Subjects of investigation of the sixth Prognoz are "corpuscular and electromagnetic solar radiation; solar plasma fluxes and magnetic fields in near-Earth space with a view to determining the effect of solar activity on the interplanetary medium and the Earth's magnetosphere, and also to carry out research into Galactic ultra-violet rays, X-rays and gamma rays."

Under the continuing programme of international co-operation for space research and exploration, the scientific apparatus carried by Prognoz 6 was made in Czechoslovakia and France as well as in the Soviet Union. The station also carries a radio transmitter, operating on a frequency of 928.4 MHz, a radio system for precise measurement of orbital elements and radio-telemetry for transmitting to Earth data on the operation of scientific instruments.

Following the successful launch, the satellite was put into an "intermediate orbit" before being injected into a pre-set highly elliptical orbit which ranges between 498 x 197,900 km inclined at about 65 edg to the equator; the period of revolution is 94 hr. 48 min.

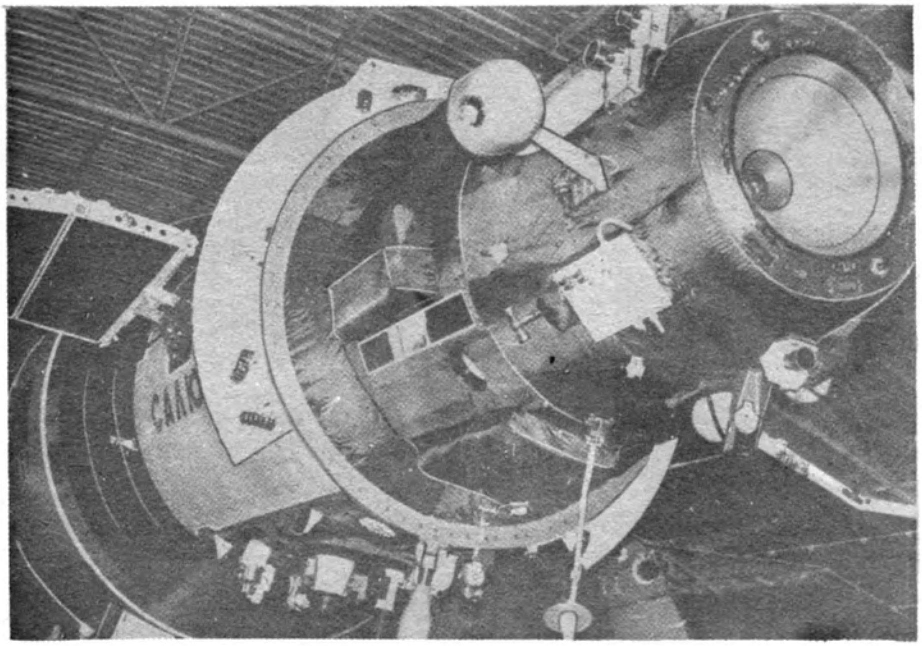
SECOND SALYUT DOCKING PORT

The long awaited second docking port on a Salyut space laboratory – long forecast in these pages – was revealed by the docking of the Soyuz 26 ferry on 11 December. The craft had been launched from the Tyuratam cosmodrome at 4.19 a.m. (Moscow time) the previous day with cosmonauts Lt-Col. Yuri Romanenko, 33, and flight engineer Georgi Grechko, 46. After completing five revolutions at 12.00 hr. (Moscow time), the craft was manoeuvred into an orbit of 267 x 329 km inclined at 51.6 deg to the equator. Its period was 90.2 min.

The docking with Salyut 6 took place at 6 hr. 02 min. (Moscow time) using the second docking port which is located on the instrument section opposite to the original port on the transfer compartment used, unsuccessfully, by the Soyuz 25 cosmonauts.

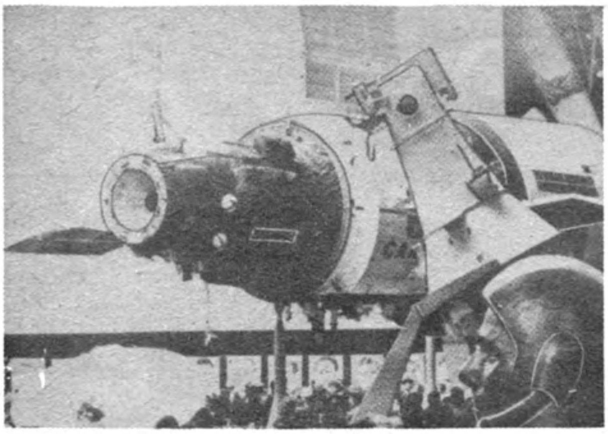
Romanenko and Grechko entered the station some three hours later after equalising atmospheres and opening the transfer hatch. Their programme was stated to include "study of physical processes and phenomena in outer space; exploration of the Earth's surface and atmosphere for obtaining data of interest to the national economy; bio-medical investigations, technical experiments and testing onboard systems and instruments. They were also due to carry out a thorough check of the docking assembly in the transfer compartment which failed to operate correctly on the previous mission.

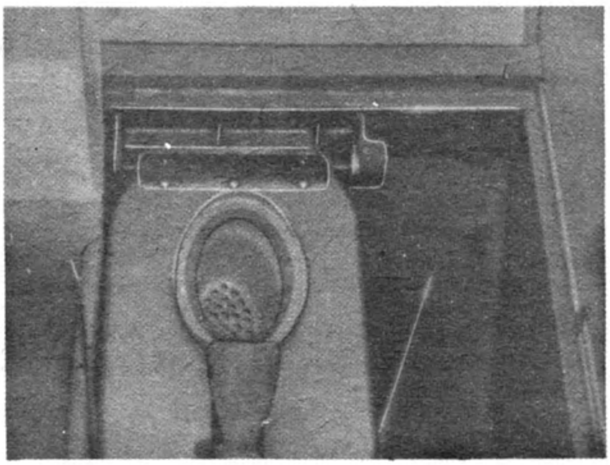
According to *Novosti*, the second docking port introduced for the first time will allow "two ferry craft to dock with a station, which is important for replacing crews, carrying out rescue operations and delivering foodstuffs and equipment."

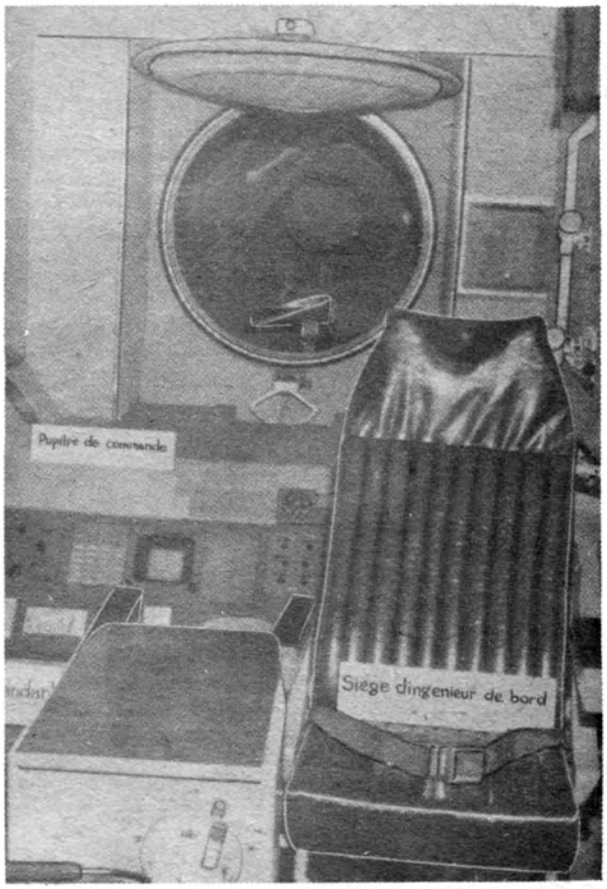


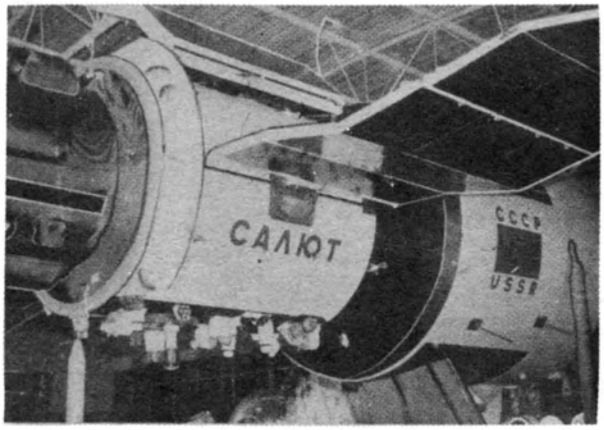
THE SALYUT SPACE STATION. *Left*, full-scale engineering replica of the Salyut 4 space station at the 1977 Paris Air Show, Le Bourget. This view shows the axial docking port and a homing antenna used in the docking operation. At the bottom are Earth sensing instruments. Note the semi-circular thermal radiator which forms a collar on the central module forward of the solar panels. *Left centre*, Salyut 4 replica with the solar telescope in the foreground. *Left bottom*, orbital toilet located in the back of the rear compartment of the Salyut space station. *Below*, Salyut interior showing the control console and engineer's seat. In the access tunnel is a small seat for making observations through a porthole.

All photos except bottom right
Theo Pirard

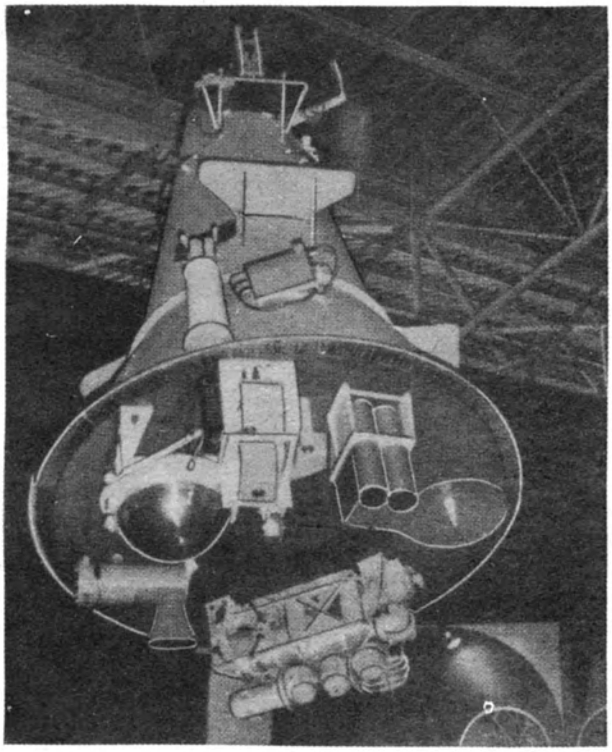




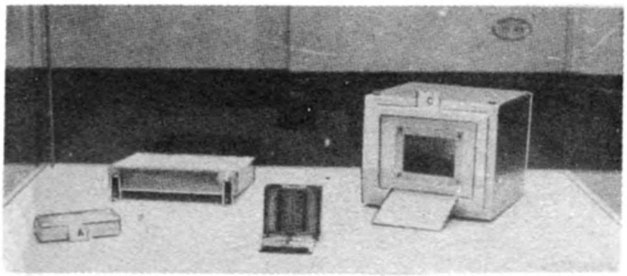




Above, another view of the Salyut space station showing the array of Earth observation equipment.

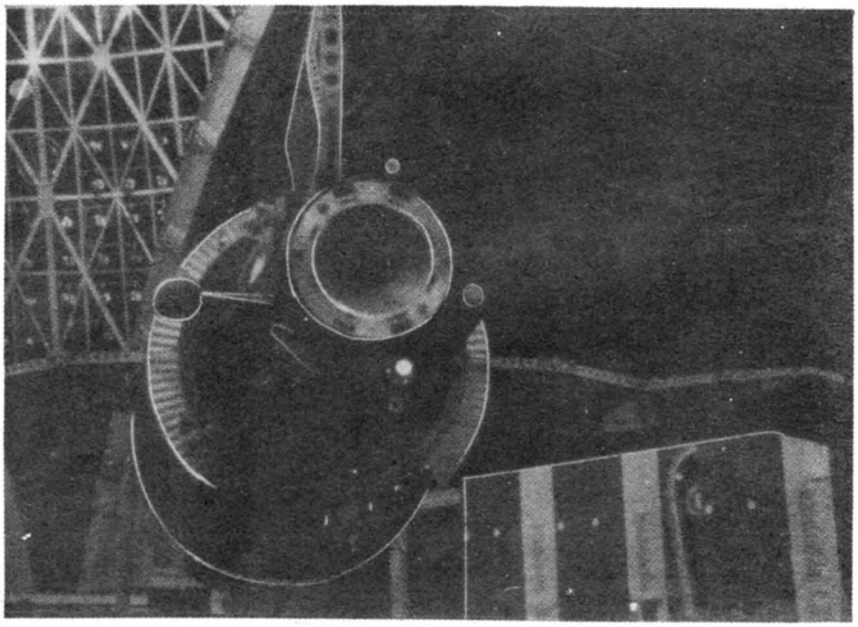


Above, the 250 mm solar telescope which is accommodated in the largest section of the space station and is directly controlled by the cosmonauts.



Above, experiment of the type which French biologists prepared for Salyut 6. Called CYTOS, it is designed to study the effect of cosmic radiation on living cells. *Right*, this picture of a Salyut space station was taken at the exhibition of Soviet Economic Achievement in Moscow.

Photo: H. P. Griffiths



SOYUZ 25 RECALL

Reports from Washington suggest that the Soyuz 25 mission was terminated because of a mechanical problem when the ferry made contact with the Salyut 6 space station. Earlier, it had been supposed that the problem had to do with the homing system which assists the cosmonauts during final approach to docking.

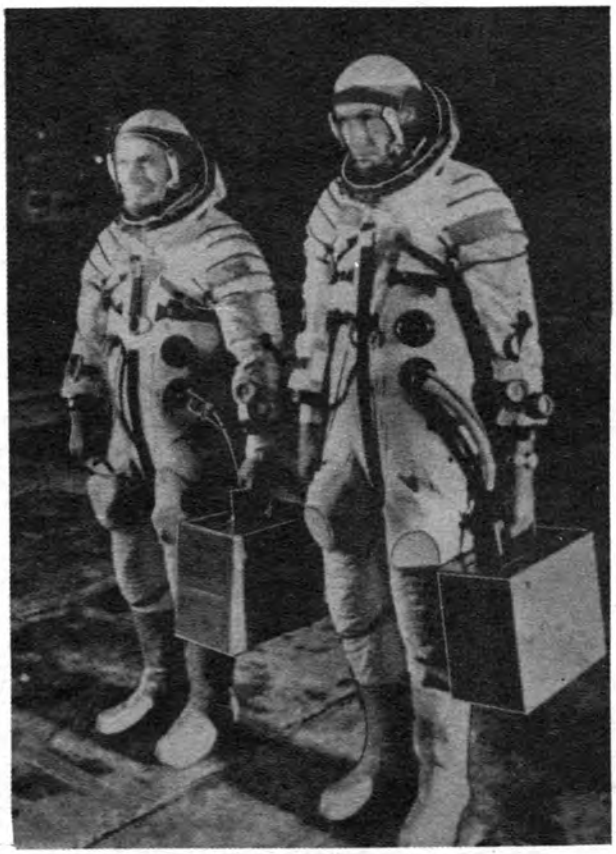
The Soviet Embassy in London had previously issued the following statement:

"At 5.40 a.m. (Moscow time) on October 9 a spaceship, Soyuz 25, with a two-man crew was launched from the Soviet Union. The flight programme envisaged joint experiments with the scientific station Salyut 6, put into orbit around the Earth on September 29.

"Following the launching, *Tass* reported that the systems of the spaceship were functioning normally and the crew – Lieutenant-Colonel Vladimir Kovalenok (Commander) and Flight Engineer Valery Ryumin – were fit and well and had begun to carry out their flight programme.

"At 7.09 a.m. on October 10 Soyuz and Salyut were brought close together by automatic means and a docking operation was begun when they were 120 metres apart. It proved impossible, however, to follow the planned procedure.

"The link-up operation was therefore cancelled and the cosmonauts began to prepare for their return to Earth.



Crew of the Soyuz 25 spacecraft which failed to dock with the Salyut 6 space station on October 1977: commander Vladimir Kovalenok (left) and Flight-Engineer Valery Ryumin. They are seen arriving at the Tyuratam launch pad carrying air conditioning units for their spacesuits.

Flight control centre near Moscow which monitors Soyuz missions after the handover from Tyuratam. The screen shows a television picture of the Soyuz 25 cosmonauts in orbit.

Novosti Press Agency

"At 6.26 a.m. today (October 11) they made a successful soft landing at a point 185 kilometres to the north-west of Tselinograd.

"Vladimir Kovalenok, the commander of the spaceship, was born in the Minsk Region in 1942.

"After studying at the Balashov Higher Air Force School he served with the military transport aviation. He is an instructor for Air Force paratroop training. He was enrolled in the cosmonauts' detachment in 1967.

"Valery Ryumin, the flight engineer, was born in 1939 at Komsomolsk-on-Amur. After completing his studies at a specialised secondary school he served with the Soviet Army. In 1961 he became a student at the Moscow Forestry Institute.

"After graduating from the Institute Valery Ryumin worked in a design bureau where he distinguished himself as an engineer with great knowledge and initiative and took part in the development and testing of new models of space equipment. He is an expert on electronic control systems. He joined the cosmonauts unit in 1973.

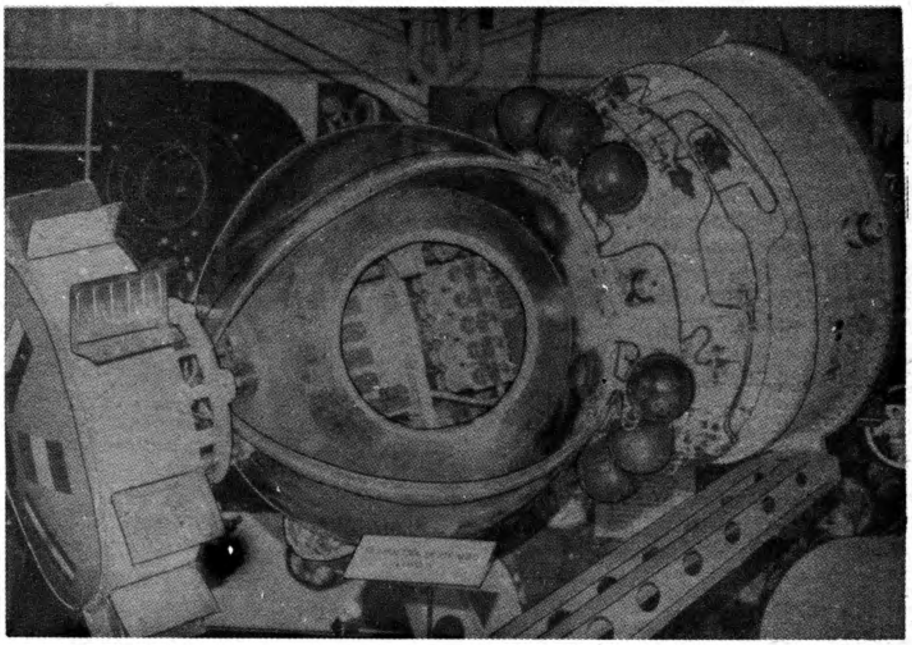
"For the 35-year-old commander and the 38-year-old flight engineer this was their first space flight."

VOSTOK BIO-SATELLITE

Another significant exhibit making the rounds of Soviet space exhibitions is an international bio-satellite adorned

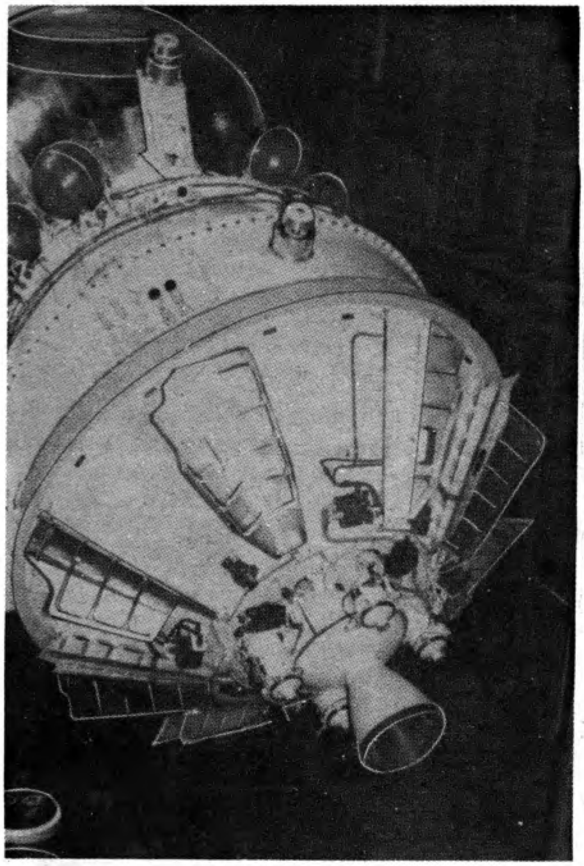
Right, replica of Soviet bio-satellite representing the Cosmos 782 which flew during 1975 carrying a cargo of live animals, tissue cultures and plants provided by countries of the Intercosmos group and the United States. Another recoverable satellite of this series was Cosmos 936. *Below*, retro-rocket at the base of the Soviet bio-satellite. The craft is based on the Vostok re-entry vehicle with a modified service module. Similar vehicles may have been used as reconnaissance satellites within the Cosmos programme

Theo Pirard



with the flags of several nations including the United States of America. The inference – although it is not spelled out – is that this represents the Cosmos 782 which flew in 1975 carrying a cargo of live animals, tissue cultures and plants provided by a number of countries from the Intercosmos group and the United States, writes Robert D. Christy.

Cosmos 782 provided a welcome opportunity for American scientists to fly biological experiments, their previous opportunity having occurred in 1969 with Biosatellite 3.



The re-entry module of the craft examined at the Paris Air Show is the spherical landing capsule of the Vostok manned spacecraft of the early 1960's. The service module is larger than that of the standard Vostok and the associated increase in weight may have been responsible for the switch from the A-1 to the A-2 launch vehicle for this type of craft in the mid-1960's.

The spacecraft is about 5 metres long and 2.3 metres in diameter and attached to the forward end of the re-entry module is a supplementary scientific package – basically a cylinder of about 2 metres diameter and some 0.5 metre deep. Another scientific package from a second satellite was displayed nearby, this specimen having a long magnetometer boom. Temperature control of the packages and of the spacecraft service module is by means of louvres, a feature also found on Vostok.

It appears likely that early Cosmos recoverable reconnaissance satellites were also of this Vostok configuration. However, some authorities suggest that current reconnaissance vehicles capable of carrying out orbital manoeuvres, are based on the manned Soyuz craft. The appearance of Cosmos 782 in Paris, clearly showing Vostok type hardware, suggests otherwise. Such vehicles can easily be adapted to carry a re-startable manoeuvring engine in place of the scientific package. The major advantage of Soyuz over Vostok as a manned spacecraft is its low-g re-entry and retro-rocket softened touchdown – luxuries which are probably not needed for the types of unmanned payload carried under the Cosmos label.

CLOUD LABORATORY IN SPACE

The old saying, "Everyone talks about the weather, but nobody does anything about it," may soon be put to rest by space age engineers and scientists. NASA and the General Electric Co. of the USA are to build a special weather laboratory that will be carried into space by the Space Shuttle and its Spacelab in the early 1980's to study the cause of weather here on Earth. NASA and General Electric signed a $5.6 million contract to build the laboratory called the

Atmospheric Cloud Physics Laboratory (ACPL) last September.

In the weightless environment of space, this highly sophisticated automated laboratory will be able to perform weather experiments that have not been possible on the ground. Years of study have yielded a wealth of data on weather phenomena, but scientists have never been able to study properly the minute physical processes of cloud formation. Earth's gravity distorts experiments and renders the results incomplete. Now, NASA may have found a way to help these scientists fill in some of the blanks.

Charles R. Ellsworth, manager of the cloud physics laboratory task team at the Marshall Space Flight Center, explains two of the problems caused by gravity in Earth-bound laboratories:

"In an experimental cloud chamber on Earth, drops form and fall out of sight so quickly that they cannot be observed properly. In space, without the pull of gravity, the drops form and remain suspended so that the formation process can be observed as long as necessary.

"Convection, or movement of air or fluid, is an effect of gravity that occurs in cloud chambers when temperature differences are present, such as a higher temperature on one side of the chamber. This effect distorts the cloud formation procedure. Convection does not occur when there is no gravity.

"This new laboratory operating in orbit will essentially eliminate problems caused by gravity and allow scientists to study the microphysical processes of cloud formation without that hindrance."

NASA has selected eight of 26 experiment proposals submitted by the scientific community to be performed in the ACPL on early Spacelab missions. The laboratory will remain in Spacelab during the mission and return to Earth with data from the experiments. The ACPL can be used many times on such missions, giving other scientists an opportunity to carry out different experiments and research leading toward their ultimate goal of controlling local weather.

SHUTTLE MATERIALS PROCESSING

NASA has selected five materials processing experiments to be packaged and flown on the Space Shuttle during one of its six Orbital Flight Tests (OFT), providing scientists an interim opportunity to conduct investigations prior to Spacelab missions.

The experiment package, called the Materials Experiment Assembly (MEA), will be first flown on one of the early orbital flight tests that are scheduled to begin in 1979. The MEA will be in regular use in later Shuttle flights on a space-available basis.

Experiments for the first MEA package were chosen because they could easily adapt to hardware available from the Space Processing Applications Rocket (SPAR) programme and could be fitted into a compact assembly that requires no interface with the Shuttle except for one command from the cockpit to start the experiment processes.

Occupying a relatively small space, the MEA package will be automated and unattended. In addition to the experiment equipment, the package will contain its own power source and a mini-computer to collect data.

Tommy C. Bannister, management coordinator for the MEA project at NASA's Marshall Space Flight Center, Huntsville, Alabama, said that besides the tremendous interest by scientists throughout the world in this early opportunity, this will be the first chance to try out a new low cost packaging concept that omits extensive ground testing prior to flight.

"To design and assemble the MEA package so that we get good results from the experiments, using available hardware and omitting extensive ground flight tests, presents a challenge that we are excited about," Bannister said. "If we are successful in keeping costs down in this way and still get the data we want from the experiments, we will have reached an important milestone on the road to processing materials in space."

The space processing programme began with five science demonstrations on Apollo missions 14, 16 and 17, and continued on Skylab and the Apollo Soyuz Test Project. The SPAR project, with sounding rockets, is now providing continued flight opportunities until the Shuttle and Spacelab become available. Each SPAR flight provides about five minutes of low-gravity time for experiments during the rocket's coast phase.

The Shuttle orbital flight test will provide scientists with an interim opportunity for longer duration experiment time, allowing them to obtain additional technical and scientific information about their experiments prior to Spacelab missions.

Principal investigators and experiments selected for the MEA project are:

- Dr. J. Bruce Wagner, Jr., Arizona State University, Tempe – *Solid Electrolytes Containing Dispersed Particles.*
- Ralph A. Happe, Rockwell International, Downey, California – *Containerless Preparation of Advanced Optical Glasses.*
- Dr. Herbert Wiedemeier, Rensselaer Polytechnic Institute, Troy, New York – *Vapour Growth of Alloy-Type Semiconductor Crystals.*
- Dr. John W. Vanderhoff, Sinclair Laboratories at Lehigh University, Bethlehem, Pennsylvania – *Large-Particle-Size-Monodisperse Latexes.*
- Dr. S. H. Gelles, Gelles Associates, Columbus, Ohio – *Liquid Miscibility Gap Materials.*

NON-SOVIET COSMONAUTS

Flights of non-Soviet cosmonauts are expected to begin in the autumn of 1978, according to cosmonaut Georgi Beregovoi. First candidates are from the German Democratic Republic, Poland and Czechoslovakia.

SKYLAB RE-VISIT?

A possible re-visit to the Skylab space station is still under consideration at the Johnson Space Center in Houston, writes James Oberg. An early Shuttle flight has been pencilled in to attach a booster stage to the derelict. Every possibility is being considered, "from dumping it to repairing it."

Launched on 14 May 1973, the 77 tonne space station was originally given a lifetime of about six years. No provision was made to de-orbit the vehicle over a predetermined area as in the case of the Soviet Salyut space stations which are made to descend over the Pacific Ocean following a retro-rocket burn.

NEXT MONTH

In the March issue: 'Martian Dust Storms: A Mechanism for the Transportation of Life?'by Geraint Day, and 'United States Missile Ranges' by David L. Skinner.

ON HUMANITY'S ROLE IN SPACE

By Jesco von Puttkamer*

Introduction†

The role of humanity in space seems to fall naturally into two categories:

(1) the *utilization of humans in space*, with their unique capabilities and attributes in order to serve the direct and indirect needs of humankind, and

(2) the *existence of humans in space* for humanistic interests, including sociological, societal, political and ethical reasons.

In this view, the Humanization of Space is seen as a dichotomy: seeking ways to open up space for humanity, and bringing space down to Earth for use by humanity.

Man *versus* Machine

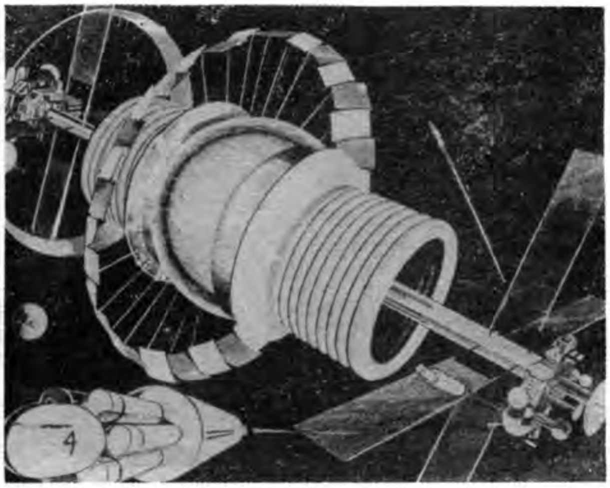
Over the first decade of the space programme, there was much debate of the relative merits of "manned" *versus* "unmanned" space flight. The term "unmanned" was meant to imply "automated" or "remotely controlled" spacecraft since man is ultimately involved in each and every space mission – only his location is the issue. Thus, the question really was: Should the human be on the ground, operating his instruments remotely, or should he be present in the spacecraft? As corollary to this we are asking: What is his purpose aboard the spacecraft?

To ask, what is man's role in space is to ask about man's role on Earth.

In a narrow sense, it may be argued that humans compare to automated systems in space in the same way they compare to automatic machines on Earth. Their role is a function of the technology at the time and the economy behind the division of manned and automated operations. While the relative emphasis between the two has naturally shifted with time, there has always been a balance. Such balance will also establish itself in space, driven by technological "can do" on one side and the desire for economy in doing it on the other side. Man's purpose in space, thus, in a very direct, materialistic sense comprises primarily utilitarian roles, deriving from his capabilities and attributes.

In its widest sense, however, man's role in space – as his role on Earth – also must relate to his needs and desires as an intellectual, social, and ethical being. Some of these needs and desires may be less tangible than his utilitarian functions and may be open to ideological argument regarding their relative merits and priorities, but they are nevertheless most important attributes of his make-up. Thus, there is also a humanistic role of man in space which derives basically from his needs, desires, and aspirations.

It was largely for humanistic objectives that the Mercury, Gemini and Apollo programmes were undertaken. Their most important impact was in the political and sociological areas of international prestige, morale, and national identity. The highly visible character of Apollo not only enhanced the average citizen's pride in his country but also provided timely proof to other nations that the United States would not be relegated to second place in a new area of endeavour having strong political and military overtones. Of course, the contributions of the Apollo Programme to science and technology as well as to applications areas on Earth were of considerable import, as was its role in laying the groundwork and providing the confidence for continued space flight, but the driving force behind it was humanistic – in a very broad sense.



A possible space habitat for some 10,000 people, according to a 1976 Study on Space Manufacturing at NASA's Ames Research Center. The Colonists, members of a space engineering workforce, would live in homes on the landscaped inner surface of the central sphere nearly a mile in circumference which spins to provide Earth-like gravity conditions. The habitat would be shielded against cosmic rays and solar flares by a non-rotating spherical shell made from the slag of industrial processes using lunar surface material. The tube-like sections are agricultural units, the rectangular panels are to radiate away waste heat of the habitat into space. At each end of the space community are docking points and micro-gravity industrial areas.

National Aeronautics and Space Administration

Unlike Apollo, the prime objectives of the Skylab Programme were more utilitarian in character. The experimental space station Skylab was designed for the demonstration of the immediately practical utility of man-in-space, based on the existence of instantaneous and continuous views of the Earth, the Sun and deep space for observation, data management, and equipment operations. The larger objective of this mission, however, was the acquisition of basic knowledge, i.e., the more indirect utility of humans as scientific researchers and experimenters, as well as medical and behavioural subjects, benefitting from the continuous absence of gravitational stress and the continuous availability of a clean, ultra-high vacuum.

As pointed out before, man's role in space is identical with his role on Earth, with the promise of additional greater roles opening us as space, by virtue of the Space Shuttle Programme, becomes his natural environment and habitat. Thus, unlike the activities of the pre-Shuttle era, there can also be no dichotomy of "manned" *versus* "automated" in a space programme integrated into society as a major part of it. With the flexible operation of the Shuttle and associated systems aimed at serving both manned and automated systems in most economical inter-

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† *The ideas discussed in this article are based on personal opinions of the author and do not necessarily represent NASA policy.*

action (that is, mutually compatible instead of exclusive), the mutual interaction of man and machine on earth will also become possible in space. It is this basic concept which underlies the third industrial revolution – the industrialization of space.

Role of Space Automats

In space industrialization, while manned and automated activities have their own role both in concert and separately just the same as on Earth, with the advent of the Shuttle's capability of routine transportation into and out of space and the emergence of thrusts toward permanent space occupancy, the distinction between manned and automated missions becomes blurred as they come together into a unified approach. In this evolving picture, automated satellites will do repetitive tasks of sensing, sorting, data processing and transmitting, recording, transponding and space housekeeping best suited to automation, while humans are required for testing, checking out and launching these satellites as well as retrieving, servicing, trouble-shooting, refurbishing and repairing them. For larger space-based systems, fabrication and assembly will be additional functions of humans in space, assisted by specialized automats such as beam builders, assemblers, and monitors.

In this new approach to space flight, failures of space facilities due to small (but critical) faulty or worn components will be intolerable regardless of whether they are manned or automated. No matter what strides are made in reliability and long lifetime capability – provisions for manned maintenance, servicing, repair and modification will become increasingly important. Conversely, the presence of humans on-site to perform these functions will make it feasible to undertake research utilizing such advanced state-of-the-art devices and instruments that their inclusion in a fully automated set-up would entail unacceptable levels of risk. Having this higher level of sophistication will allow a more versatile and adaptive research approach, greater precision and resolution, and – in general – better research throughout with better results.

The Human Factor

On the other hand, man in space can be a liability. He requires his own environment, creates contaminants and motion disturbances, and he may require early mission termination due to emergencies. Having humans on-board requires additional structural weight for their accommodations and return, and imposes psychological and physiological constraints. However, after the experience of the past manned programmes these liabilities and their relative impacts are well understood. For missions of higher complexity and weight, the resulting payload reduction becomes secondary to the gain in payload efficiency due to absence of need for those additional systems, propellants, analyses and developments required for automatic or remotely-controlled function. Man should be used if he is the most economical functional subsystem with regard to expenditure of time and effort per unit "payoff" or result.

In general, then, we can conclude that humans have a distinct practical role in space wherever (1) automation or remote control is not feasible; (2) automation or remote control is not practical, and (3) the total job is complex, and man is more cost-effective.

Human capabilities and attributes make man uniquely useful for a number of functions which increase considerably our options to explore and use space. Conversely, if humans are eliminated from space flight, these options will be reduced significantly.

Man as *researcher* uses his capability to observe and act upon unforeseen phenomena and events, utilizing judgment, experience and skills. In this respect, the Space Sciences Board of the National Academy of Sciences concluded in 1961 that, "Man can contribute critical elements of scientific judgment and discrimination in conducting the scientific exploration of these (celestial) bodies which can never be fully supplied by his instruments, however complex and sophisticated they may become. Thus, carefully planned and executed manned scientific expeditions will inevitably be the more fruitful."

Man as *data integrator* can attend selectively to phenomena that are unexpected occurrences, especially if he is well-trained and experienced in the subject area. He is required to establish priorities for observations, provide flexibility to pre-programmed observations when needed due to unforeseen transients, and select phenomena and data for subsequent analysis. He is needed to perform quick reaction analyses of data based on his visual observations and to use his expertise to filter data in order to delete "noise" and redundancies for maximum data utility and availability.

Man as *experimenter* must use his flexibility to execute changes in experiment protocol and programming, and to allow reduction in complexity of equipment intended to respond to changing phenomena. He provides on-board capability for equipment diagnosis, repair and modifications, including substitution of experiments, in whole or in part, as failures occur or systems operate in degraded or outdated modes.

Man as *systems operator* is necessary to increase overall systems reliability and to improve the probability of mission success. By his ability to perform extra-vehicular activities, he can repair, adjust or replace malfunctioning systems. The combination of complex system and highly reliable system can *only* exist in the presence of man as systems monitor (observer), decision-maker, and operator for maintenance, servicing and repair.

Man as *cost saver* is an important role which derives from the reduction in complexity of systems when experimenters are present on board. In addition, with man in the loop, systems can be designed to a lower reliability than that required by automated or remotely controlled systems without regular human visits for purposes of servicing. This man-tended activity will also be highly significant in the erection of large deployable or space-assembled structures, such as energy collectors, antennae, reflectors and solar panels.

Needs and Desires

There are obvious limitations on our ability to define the humanistic aspects of manned space flight in the same clearly quantified manner as the more practical, pragmatic roles of humans in space. Some may be considered more intuitively and many will require philosophical argumentation. but if we ask now not so much for man's general roles in space (i.e., not *what* may be), but rather *why* there appears to be such urgency for humans to continue their emergence into space *now*, then we must touch on their needs and desires and on the possible fulfillment of these by man's active participation in space flight, even if we must call on philosophical arguments of ethics, on beliefs and opinions rather than on proven functions and rational projections.

The needs of humans and their desires are manifold and diverse. They vary for each nation and society, for each group and individual, and they also vary in time. Basic to all people past, present and future is the need to improve general welfare and the quality of life. While for some people quality of life is represented by basic elements whose lack affects physical well-being, such as food, shelter, health, etc., for others – such as growing and affluent nations – quality of life involves both physical and humanistic factors, such as energy, natural resources, balanced ecology, efficient transportation, industrial productivity, national and international economics and balance of trade, world politics, national and global conflicts and peace, meaningful work,

TOWARD THE HUMANIZATION OF SPACE

1980 - 1990: DIRECT SERVICES AND NEW PRODUCTS FROM SPACE (near-earth orbits)
- Electronic Public Services
- New Products & Goods
- Space Construction & Space Power Experiments/Tests (R&D)

1990 - 2000: PROVING OUT THE ENERGY OPTIONS FROM SPACE (near-earth & geosync)
- Energy Technology and Initial Operations
- Illumination from Space (small-scale Lunettas)
- Products/Profits "made in Space"
- Return to the Moon
- First Private Orbital Travellers/Tourists

2000 - ___: SPACE FLIGHT REACHES MATURITY (near-earth, geosync, lunar, beyond)
- Abundant clean Energy throughout 21st Century (solar/nuclear)
- Major Industry in Space
- Materials from the Moon
- Local Climate Control
- Space Sciences Center in Orbit
- Space Tourism & Space Therapeutics
- Permanent Habitats with Increasing Autarky

creativity, recreation, cultural activity, etc.

The quality of life of humans, thus, relates to all needs and desires of physical, psychological, sociological and spiritual character. In order for man to maintain mental and physical health, he has to have all these needs fulfilled to some relative extent – a goal which is the basic motivation of human endeavour.

The contributions by manned space flight to the attainment of this goal have been identified in the past again and again; after a small beginning with John Glenn's ride on Mercury, they have proliferated rapidly, and Apollo and Skylab have added a multitude of new aspects. We can confidently predict that in the world of the future, manned space flight will assume a major part in man's striving for improved quality of life.

We are now living in a time in which it is becoming increasingly difficult to anticipate and deal with humanity's long-term needs and desires. The near-term need for better standard of living and improved quality of physical life is one of the most basic, most pressing concerns of our time. It involves such deficiency factors as food, housing and shelter, energy, transportation, communications, health care, and education. On the national level, manned space flight – through space industrialization – will relate to this problem complex by increasing scientific knowledge and advancing technology, by creating new values, producing anti-inflationary factors and promoting economic welfare, and by providing communications and education, better management of natural resources, better health care, and new sources of energy.

On the global scale, humans in space will make additional contributions by promoting world-wide economic growth, fostering international cooperation and world peace, aiding in the identification and distribution of food sources and other resources, and providing much needed services, energy and products to underdeveloped and underindustrialized nations.

What makes our times so difficult is the high sense of urgency for action permeating the image man has of his world – a world of rapidly deteriorating quality of life. With humanity's concerns about dwindling resources and an endangered biosphere, whatever action is taken on Earth or in space must seemingly be effective soon. For manned space flight, this means that the developing pressures could eventually amount to a "critical mass," the existence of which could conceivably be recognised only when it is too late. It may mean that space flight should use man's great potential today in a manner that minimises the chance of loosing an opportunity now that only later, by hindsight, will show up. Can we ethically afford foreclosing on the future?

Krafft A. Ehricke has compared our dilemma to the situation of an unborn child in the eighth month of pregnancy: it is getting crowded in the womb and the pollution level is building up. Any projection of the future made by the unborn human might indicate to him that in the tenth month things will become very bad indeed and, in the twelfth month, impossible.

The potential contributions of human space flight to the successful ninth-month birth and growth of our unborn being have been proposed in a number of humanistic areas.

Psychological Aspects

Among the psychological impacts of human space flight is, first of all, the fact that the involvement of man generates maximum public visibility and excitement as well as international interest and focus. It is probable that without the manned programme it would be considerably more difficult to obtain Congressional and public approval for the space programme.

What specifically in manned space flight inspires the public and its representatives?

It is certainly not one single aspect but a combination of aspects in highly complex interaction. One factor may be the visible socio-economic value of manned space programmes – the practical benefits such as the cooperation with other nations (*viz.*, ASTP, Spacelab) or the contributions to world communications and the energy problem. Another factor is pure self-projection, the vicarious relationship between the average human on Earth and the human flying in space, similar to the moviegoer who identifies with the man on the screen.

A third factor is the curiosity and interest for the new, the witnessing of something unprecedented, unheard-of which represents new, little understood information. A fourth factor, for both the politician and the constituent, is the practical, pragmatic return to him of some real value, money or other. It is essentially a combination of these fundamental factors that provide psychological motivation to the "man on the street."

There is also a psychological need for people to satisfy a strong desire for positive accomplishments – on the personal, national and global level. In the past, the average US citizen has shown considerable interest in elements of the NASA programme and pride in the NASA accomplishments. This was particularly true in the manned space programmes. Elements of psychic well-being resulted from the past programmes and should be a valid goal for the future.

On the global scale, with ever-increasing communication and transportation coverage provided by technology, the global complex is shrinking increasingly towards a "global village." There is a strong psychological need for humankind's young to counteract the growing feeling that eventually nothing is left to put an "individual mark" on – a feeling which will prevail with the young generations and may cause an inward- and downward-turning of spirit.

In the past, the youth of the world have reacted to manned space flight with enthusiasm and hope. New frontiers are needed by growing man to test his endurance and perseverance, and space is a new frontier. Space Occupancy and continued exploration will provide the psychologically necessary awareness that there is "space-to-grow" – physically and mentally.

Sociological Impacts

The sociological relevance of manned space programmes derives primarily from the ramifications of life in what may

appear to be a closed community. Within this world there is bound to be increasing concern and anxiety about factors such as social rights, medicine and health, education and welfare, meaningful work, job availability and satisfaction, and leisure time. The potential implications of developing human occupancy of space should be obvious.

Of particular significance appears to be space flight's potential for education beyond the near-term concept of an educational satellite system. For example, by introducing a space education facility in Earth orbit for students of all ages, space flight could be offered to students of all disciplines and races, male and female, from the nuclear physics major to the medical student and to the poet, painter, and novelist. These students could represent all nationalities, contributing to bringing the world community closer together. The stimulation triggered in young minds by a week or summer in space defies the imagination today, but the experience from Skylab with its students' experiments and science demonstrations allows us to consider education in an orbiting classroom a rational possibility with mind-staggering social impacts.

A more distant role of human space flight in social developments, the factor of "humankind's survival," is nevertheless of timely interest today. With the ever-increasing capability of man to cause destruction of his world on a global scale, it could become increasingly important for him to have an escape route, a "fire exit." In a closed system, there is no escape. Once self-sustaining communities in space are established, the human race would go on even if there is a disaster on Earth, an environmental catastrophe, a nuclear holocaust, or a major climatic change due to changes in the Sun.

Societal Aspects

With "societal" we classify factors involving forms of society, styles of life, and the concepts of human conflict and peace.

Permanent occupancy of space, space industrialization and – eventually – space settlement may indeed produce new and better socio-political patterns of human organisation, similar to the new life style of democratic principles evolved by the settlers of America.

There is also manned space flight's contribution to world peace to consider. By the very global nature of its systems and operations, the space programme is a strong stabilizing force for unification of the world and thus prevention of conflict. Indeed, the contributions to world peace may be its most important intangible benefit. When Neil Armstrong set foot on the Moon there was a universal feeling of unity of purpose and accomplishment of Humanity rather than only a national feat. The Apollo 13 crisis united all nations, if only for a few days. When its crew was in jeopardy, people of all races and religions prayed for their safety, and 17 nations actually offered assistance to NASA in spacecraft recovery. Programmes such as the Apollo-Soyuz Test Project and Spacelab hold out the promise of ameliorating attitudes, viewpoints and expectations throughout the world. These programmes, along with the widening internationalising of the space programme in the future (made increasingly desirable by economic considerations), are powerful "weapons" for peace and mighty deterrents against isolationism.

Political Factors

Political factors, particularly at the international level, are at present of major import. While social factors of the space programme could be assumed a primary influence in the world, it is probably more realistic to recognise the political estimate of this social influence as the chief factor.

The accomplishments in the US manned space programme have been extremely effective in generating a unique technological and emotional bond between all of the nations of the world. For US international relationships, it probably accomplished more than most federal programmes specifically designed for such purpose.* In the future, the concept of international participation – always a key element of NASA's charter – will be expanded to include physical participation by foreign personnel, such as exploration and use of space. The image of probing exploration by humans, strong technological development and peaceful applications elicits great prestige value while, at the same time, carrying an awareness that such technology is on hand to apply to national security.

Ethical Implications

Human ethics includes intellectual, moral, spiritual, religious and other factors. Curiosity, love of adventure, search for truth, goodness, justice, wisdom and beauty, belief in higher goals, etc. are recognised manifestations of human ethics.

For example, the participation of humans in space flight *may* indeed be necessary to help fulfill certain ethical/spiritual needs of man, namely (1) identification of all kinds of people with the process (vicariousness); (2) awareness of creation and destiny; (3) stimulation of sense of oneness of human species, and (4) stimulation of sense of "helping each other" for mutual benefit of all, i.e., recognition of compassion and altruism.

The psychic need for exploration *for the sake of it* is a typical basic requirement of people when threatened, disturbed, oppressed and frustrated. Nations have become eminent not only for their scientific achievements and accumulation of real values but also for supporting manned exploration, even when no practical returns resulted. The exploration ethic requires that the endeavour be "hazardous," unique and highly imaginative. Historically, it seems such endeavours have often been rationalised with political or – mostly – economic purposes and as such been used as political tools by the decision-makers.

To continue explorations from the fully explored region of near-Earth space, deep-space expeditions by humans will become increasingly acceptable in the long-term future. As a precursor to deep-space exploration, permanent occupancy of geocentric space will be a necessary step in order to develop such technologies as long lifetime systems reliability, closed-loop life support systems, power supplies, and physiological and psychological conditioning and motivation.

Human ethics includes also religious thought. Religious aspects of space flight were highlighted when Francis B. Sayre, Dean of the Washington Cathedral, blessed the "space-window" of the Cathedral on the occasion of the fifth anniversary of the Moon landing by Apollo 11. In his special address on the spiritual significance and religious implications of the programme, Dean Sayre referred to the biblical crossing of the Galilee Lake by Christ and his disciples:

> *"And they launched forth upon the deep." So simple, so unerringly does the Bible portray that primordial urge in Man that requires hime to trace out with his stubby finger the woundrous shape of Creation. Never may the human spirit be content to sit by the lake; Man must up, to follow his Maker across the deeps, questing after those invisible things that God has given him to find, that have to do with who he is, and what he is meant to be, and the holiness that is in all things."*

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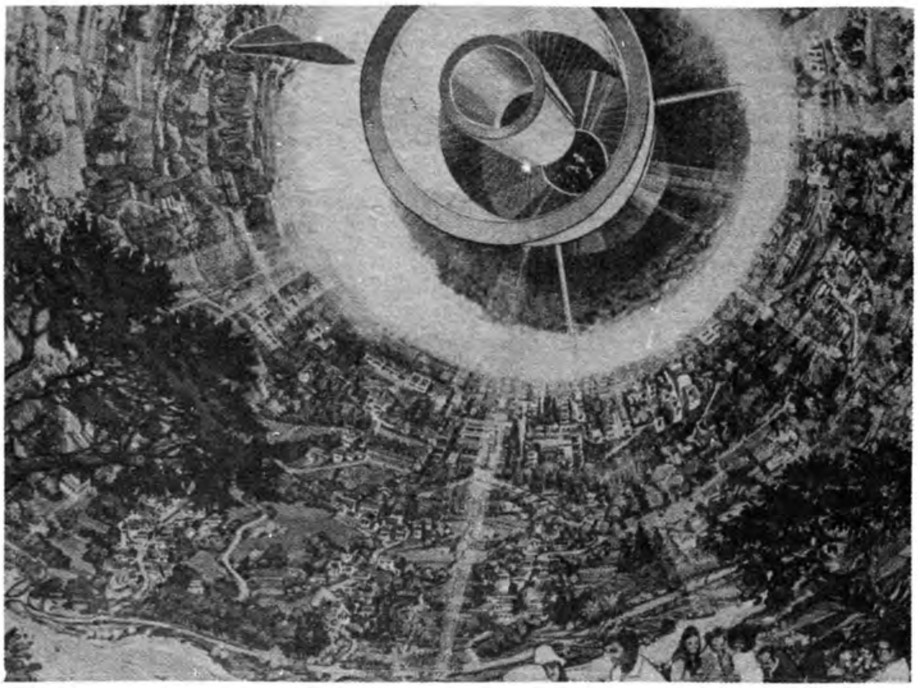
* *One possible exception that comes to mind is the Marshall Plan.*



Conceptual interior of space settlement for 10,000 people from the 1976 Study on Space Manufacturing at Ames Research Center. The equator of the spinning habitat is nearly a mile long. Near it wanders a small river with shores of lunar sand. Natural sunshine is brought inside by external mirrors.

National Aeronautics and Space Administration

Evolution and Destiny

Progress in any new area of human endeavour always begins with exploration.

The exploration of the New World carries the names of Columbus, Ponce de Leon, Coronado, de Soto, Cartier, La Salle and others. After the explorers came the pioneers. Nameless and in countless numbers and from many nations, they colonised and settled, and their goal and achievement was to replace exploration and investigation with exploitation and use. And, thus, civilisation developed.

If we see space as a new frontier, a new horizon for the whole world, then we find that the exploration phase of our history of *near-Earth* space is obviously over. History has seen, compressed into one decade of activity in space, the equivalent of two centuries of exploration of the great American West. Considerable efforts are now being expended to move on to the exploitation phase; thus, the pioneering era is just beginning. The civilisation phase is already visible on the horizon.

By accepting the "new frontier" concept of space, we are including the Universe in our natural environment and admitting that what we have done in the past decade in making it accessible to man is not only a part of history but a part of our evolution. By the use of his mind, man has made his technological evolution historically equivalent to his biological evolution. Man's evolution into space, then, is part of humanity's destiny.

Evolution is a process which requires external forces and stresses to drive it. Such drivers may be the problems of a growing society in what seems to be a closed system, that are becoming increasingly visible to us. Man's concern with his environment, welfare, and quality of life is mounting. Humanity as a whole seems to be developing a Pandora's Box of wants, desires and aspirations; deficiency needs, growth exigencies, and transpersonal problems are proliferating and of concern in the underdeveloped and emerging nations of the world the same as in middle-class society in affluent post-industrial or superindustrial nations.

With all technology and "know-how", a closed system will still mean the need for extreme conversation and limiting of growth, but in the long term this may only slow down, not stop and reverse, the decrease in quality of life – physically and mentally.

Conclusion

Without a role for humanity in space, it would at present appear difficult to point out an alternative evolutionary step and destiny for humankind.

In a world of people faced by changing attitudes and even cynicism relative to almost all "traditional" moral values, in a world in which a veritable explosion of communication flow and information exchange has led to:

- the problem of "unfulfilled expectations,"
- a no-longer-indifferent, reproachful and rebelling, confused youth,
- a world-wide wave of enlightenment, and
- the "global village" in the McLuhan sense,

Man's emergence into space – as exemplified by Apollo and the global response it elicited – has demonstrated that an aspiring spirit, an undauntable courage, and an intuitive sense of destiny are still among the dominant, and most admired, traits of humankind. To ignore the manifest need of people to see the finest humanistic attributes of man at work, by turning our backs on man's step toward more permanent mastery and occupancy of space, would seem inexcusable and indefensible, and – in the longer run – utterly untenable.

In conclusion, in anticipating the future it is important to emphasise that any limits that people can now set are most likely naive. The opportunity for the growth of new worlds in space with all of the advantages that people have gained from fresh starts in creating new societies, appears to be among the potentials of space. A space programme directed toward exhibiting that there are no visible limits to humanity's future in the Universe could be a most important help in reviving faith in the idea of progress. Reconciliation of the two seemingly opposed views of solving pressing problems on Earth in the near term and of providing for man's humanistic growth in space in the longer term, should therefore be foremost among our concerns. With some distinct exceptions, it is difficult to imagine anything more relevant to our current problems.

EVOLUTION OF THE SPACE SHUTTLE

Text and drawings by David Baker

Continued from January issue, page 40]

Introduction

Evolution of the External Tank, or ET, really began in the latter half of 1971 during attempts to seek a lower development cost for the proposed Shuttle programme, in the course of which Orbiter ascent propellants were relegated to an exterior tank. The Orbiter contract was awarded to Rockwell International Space Division in July 1972 (following Space Shuttle Main Engine award to the Rocketdyne Division in August 1971) and Martin Marietta were selected 13 months later, in August 1973, to design, develop and test the External Tank. The Thiokol Chemical Corporation, were selected as Solid Rocket Booster contractor in November 1973 and this will be the subject of review in Part 9 to this series.

A unique aspect of the expendable External Tank programme is that it will probably enjoy a larger unit production run than any other single item of space hardware and it is the tallest single structure yet designed for a launch (or payload) system; in fact, one of the two propellant tanks it contains is the tallest and most voluminous vessel ever built for a rocket stage. So large is the ET that if it were a hollow structure of the same dimension (and 2 m taller) it could entirely contain early models of the Saturn 1 launch vehicle!

In a launch configuration the ET accounts for about 37% of the total mass of the Shuttle, contains more than 709,000 kg of propellants and delivers liquid hydrogen and liquid oxygen to the three Orbiter SSME units at the rate of 3,930 litres/sec. Moreover, the internal volume of the ET propellant tanks is nearly six times that of the internal volume of all elements of the Skylab space station. The Martin Marietta External Tank is the fifth cryogenic propellant stage developed for launch vehicle use, following the Centaur, S-IV, S-IVB and S-II (Saturn I, IB and V) structures.

Because of the special nature of LO_2/LH_2 stage design it inherits the unique constraints imposed by cryogenic propellant storage and an accompanying table details the evolutionary sizing of these large-scale super-cold tanks. To the end of 1976 NASA and the DoD had successfully launched 83 LO_2/LH_2 rocket stages and the Shuttle ET may ultimately bring this total close to 1,000; NASA is currently anticipating 566 Shuttle flights between 1979 and 1991 and a new ET will be required for each mission.

Structural Layout

Structural Elements

The External Tank is primarily responsible for containing, and delivering, cryogenic propellants to the Orbiter, providing a secure protection for subsystems necessary to achieve this objective and receive and distribute stress loads from and to the Orbiter and Solid Rocket Boosters. It is the main structural element supporting the Orbiter and the SRBs and as such must provide load path continuity for the Shuttle flight configuration. The three primary structural elements are a forward LO_2 Tank, an aft LH_2 Tank and an Intertank.

The ET is 47.235 m long from the tip of the lightning rod in the nose to the base of the LH_2 Tank at the rear and 840.74 cm in diameter exclusive of the Thermal Protection System. It also supports 14 attachment interface points for securing the Orbiter and two Solid Rocket Boosters at a variety of locations on the Intertank and sections of the LH_2 Tank. Launch pad tie-down locations are attached to the two SRBs (see Part 8 in this series).

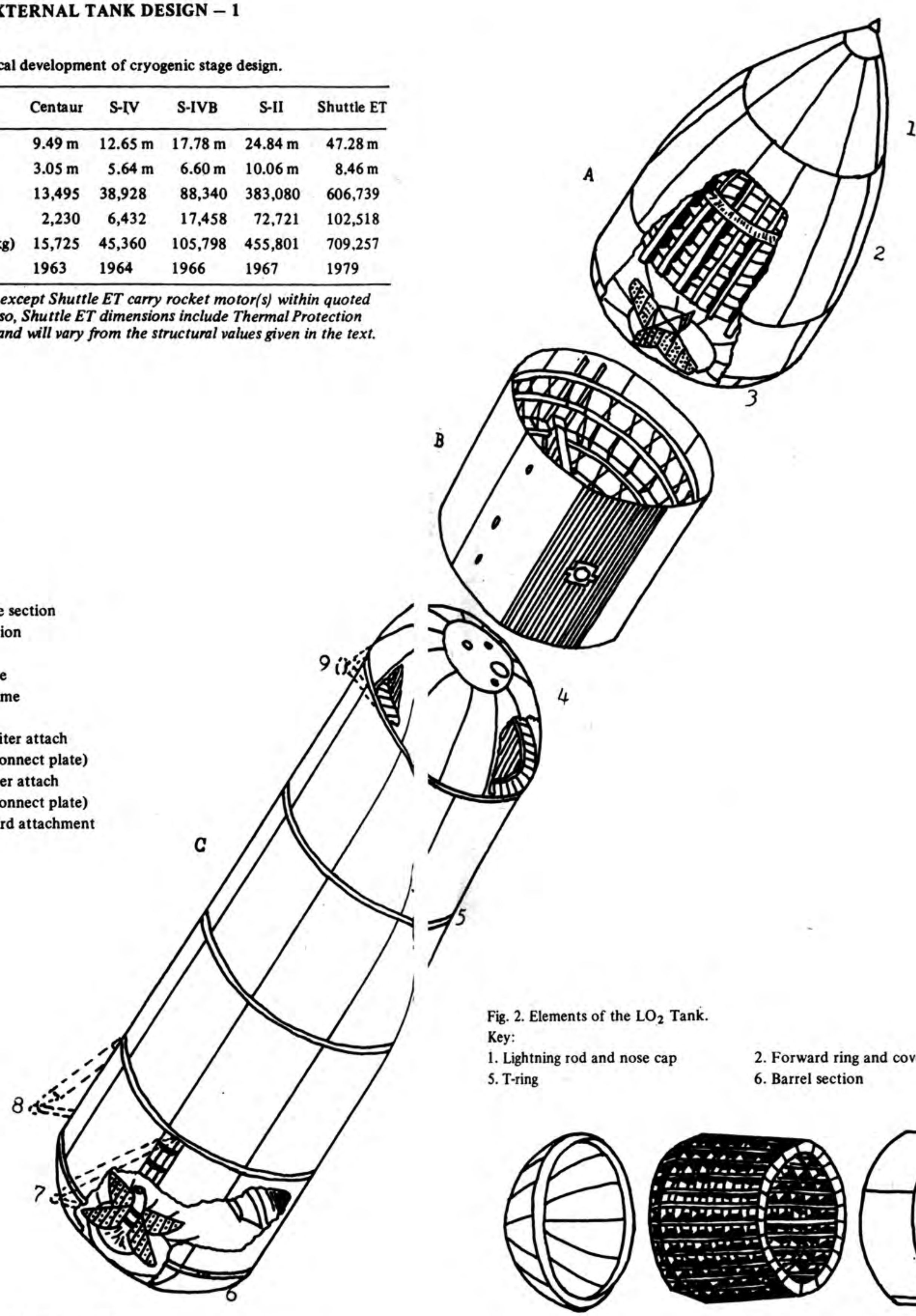
For the remainder of this report the ET is assumed to be in a horizontal position with references to the front pertaining to the nose and the rear being the base of the LH_2 Tank. With the horizontal Orbiter placed above the ET this surface becomes the top while the undersurface, 180° from the Orbiter/ET interface, becomes the bottom. The configuration will never actually be assembled in the horizontal position and readers should note that this coordinate system is for the convenience of description. Left and right references originate from positions along the ET facing the nose cap and clock rotations are similarly referenced to a forward facing view.

7. EXTERNAL TANK DESIGN – 1

Table 1. Historical development of cryogenic stage design.

Parameter	Centaur	S-IV	S-IVB	S-II	Shuttle ET
Length	9.49 m	12.65 m	17.78 m	24.84 m	47.28 m
Diameter	3.05 m	5.64 m	6.60 m	10.06 m	8.46 m
LO_2 (kg)	13,495	38,928	88,340	383,080	606,739
LH_2 (kg)	2,230	6,432	17,458	72,721	102,518
Total prop wt. (kg)	15,725	45,360	105,798	455,801	709,257
First flight	1963	1964	1966	1967	1979

Note: *All stages except Shuttle ET carry rocket motor(s) within quoted length. Also, Shuttle ET dimensions include Thermal Protection materials and will vary from the structural values given in the text.*



Key:
A. LO_2 Tank
B. Intertank
C. LH_2 Tank
1. Forward ogive section
2. Aft ogive section
3. Aft dome
4. Forward dome
5. Major ring frame
6. Aft dome
7. Right aft Orbiter attach point (or disconnect plate)
8. Left aft Orbiter attach point (or disconnect plate)
9. Orbiter forward attachment bipod

Fig. 1. Elements of the External Tank.

LO_2 Tank

The single liquid oxygen tank is a fusion-welded assembly of preformed aluminium comprising an ogive nose section (with cover plate and nose cap), a barrel section and an aft dome with a slosh baffle located inside the nose, barrel and dome sections (Fig. 2). The complete tank, with nose cap and lightning rod, is 16.65 m long with a maximum diameter of 840.74 cm.

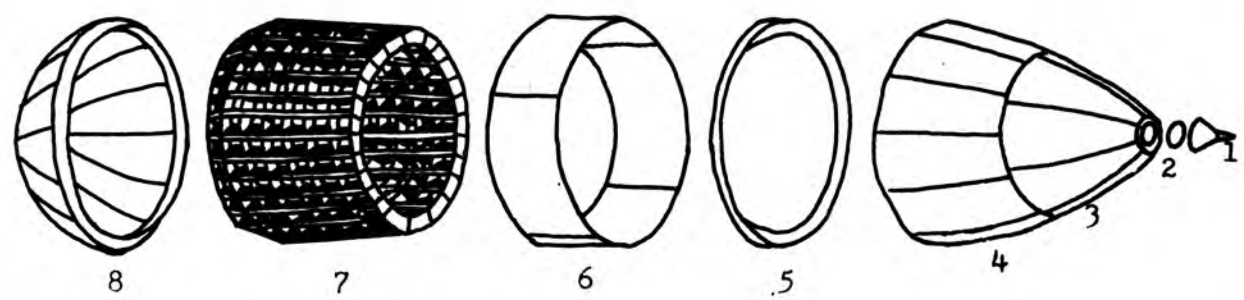
The ogive nose section consists of a forward ring butt-welded to the forward ogive section which is in turn butt-welded to the aft ogive gores. The combined forward and aft ogive section is 9.49 m long, 1.47 m in diameter at the forward ring and 8.4 m in diameter at the base of the aft section providing an ogive section contour which would be obtained from a circle of 15.54 m radius.

The forward ogive section, 4.21 m long, comprises eight gore segments with a membrane thickness of 0.02 cm at the front and 0.27 cm at the rear. Gore panel thickness in the aft ogive section varies from 0.27 cm to 0.5 cm at the rear; this section contains 12 gore segments and exhibits a length of 5.28 m. The gradual thickening of the 20 gore panels along the length of the ogive nose section conforms to increased stress toward the rear of the section. The panels are each formed to the necessary curvature and chemically milled from aluminium 2219 plate stock, edge trimmed and butt-welded with additional thickening at the edges to allow for heat stress and consequent weakening at the joins. One forward and aft gore segment is locally thickened to accept brackets for a LO_2 pressurisation line and cable tray.

The forward ring, fitted to the front of the forward ogive section by 92 0.8 cm bolts, supports a cover plate 99 cm in diameter which itself supports the nose cap and lightning rod. The nose cap is a 75.5 cm long truncated cone 17.5 cm in thickness at the forward end fabricated from 6061 sheet aluminium machined to a thickness of 0.02 cm and supporting an aerodynamic fairing for the LO_2 pressurisation line lead-in and a 5 cm pyro-tumble valve.

The nose cap is bolted to the ogive section forward ring by 18 0.5 cm bolts. The 47.7 cm long lightning rod is 17.5 cm in diameter at the base where it is attached to the nose cap by 6 0.5 cm bolts and exhibits a tip rounded to a

Fig. 2. Elements of the LO_2 Tank.
Key:
1. Lightning rod and nose cap
2. Forward ring and cover plate
3. Forward ogive section
4. Aft ogive section
5. T-ring
6. Barrel section
7. Slosh baffle.
8. Aft dome and end cap.



Key:
1. Electrical feedthrough
2. Manhole
3. Aft dome end-cap
4. LO_2 feedline
5. Antigeyser fitting

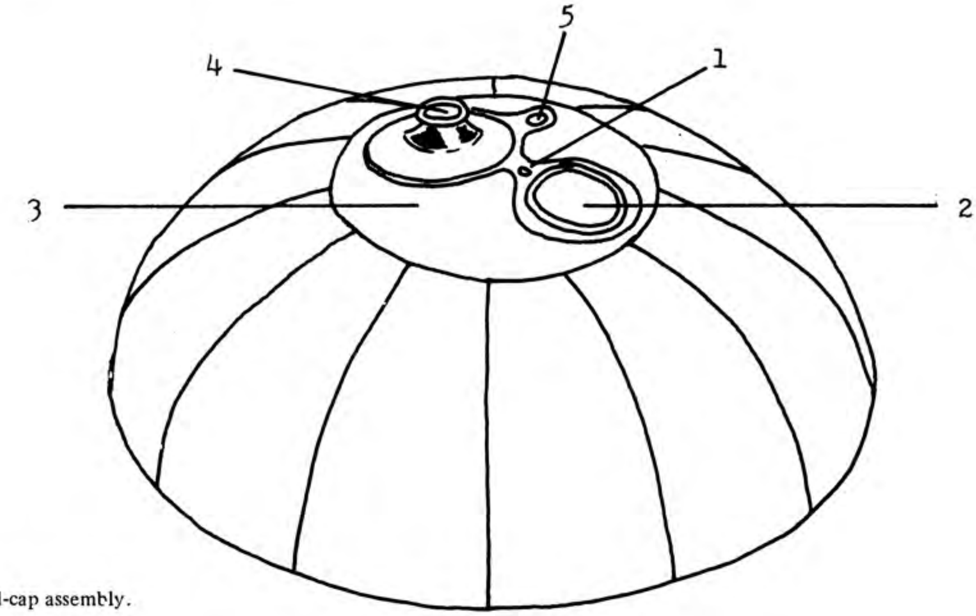


Fig. 3. LO_2 Tank aft dome and end-cap assembly.

0.4 cm radius. This averts high recovery temperatures from air flow impingement during the ascent and the double cone of rod and nose cap limits the thermal impact from shock waves which would otherwise attach flow lines to the ogive section. Access to the LO_2 tank is gained by detaching the nose cap (and its lightning rod) and then removing the 92 0.5 cm bolts holding the 99 cm cover plate in position to reveal a 91 cm opening into the tank proper.

Immediately to the rear of the circular aft ogive section is an extruded 2219 aluminium T-ring 8.4 m in diameter and 6.35 cm wide, butt-welded to the aft ogive section on one side and to the barrel section on the other side, effectively providing an interface between the two sections. It contributes to LO_2 tank rigidity and provides forward attachment for the internal slosh baffel assembly. The ring is assembled from four 90° sections.

The barrel section is a 2.49 m long, 8.4 m constant diameter, cylinder formed from four 90° chemically milled aluminium 2219 plate segments and welded together. A grid thickening process is applied to two opposing panels for accepting SRB thrust loads and one panel carries brackets for a LO_2 pressurisation line and cable tray. Panel thicknesses increase from 0.4 cm at the forward end to 0.9 cm at the rear.

The dome section (Fig. 3) provides an aft closecut for the LO_2 Tank and consists of 12 gore panels machined so as to present a 0.75 ellipsoid (where the ellipse of revolution has a height/radius ratio of 0.75). Assembly is achieved by first welding three pre-formed gore skins together and then to a 90° section of an extruded ring frame to construct a quarter-dome segment, four such sections being welded together to form the dome. The 8.4 m dome section is completed by welding a 3.55 m diameter end-cap to the segments. Chemical milling is applied to the gore panels with skin thickness varying from 0.28 cm to 0.37 cm and the end-cap has a membrane thickness of 0.44 cm with a LO_2 inlet/outlet fitting, antigeyser fitting, electrical feed-through and an access manhole.

The LO_2 inlet/outlet fitting has a diameter of 1.62 m where it is welded to the end-cap 8° off-centre from the longitudinal axis of the ET and within 1° of the thrust axis to ensure propellant delivery at SSME shut-down. The fitting flares to an internal diameter of 43.2 cm within a length of 44.5 cm and a flange accommodates 44 0.8 cm diameter bolts for attaching the propellant line which carries LO_2 down to the Orbiter interface at the rear of the ET. The 1.02 m diameter manhole is attached to the end-cap by 92 0.3 cm bolts and, when removed, provides a 91 cm opening to the interior of the LO_2 Tank similar to the nose cover at the extreme forward end.

On the interior face of the end-cap provision is made for attaching a cruciform shaped antivortex baffle assembled from 2 x 4 m long perforated I-section beams with the centre (where the beams cross) located over the offset LO_2 inlet/outlet opening (Fig. 4). The beams contain 124 12.4 cm to 15 cm diameter holes to reduce structural weight and an 800-micron screen is mounted beneath the beams and over the outlet. A splash plate is located at the forward face of the I-section beams and quantity sensors are attached to a mast on one of the beams. The extruded ring frame, to which the 12 gore skins are welded, is itself welded to the constant diameter barrel section, effectively securing the dome section and completing the LO_2 Tank structure.

The interior of the tank contains a slosh baffle fabricated from 2024 aluminium which consists of eight circumferential rings, 66 cm wide, 0.05 cm thick and with specific diameters appropriate to that of the interior of the aft ogive nose section, the cylindrical barrel section and the ellipsoidal dome section, (Fig. 2). The rings are typically 89.6 cm apart and supported by 32 longitudinal stiffened webs providing the slosh baffle with a length of 6.25 m (Fig. 5). From the forward end of the slosh baffle, which protrudes about 2.67 m into the aft ogive nose section, ring No. 4 has a 0.08 cm web so that it can be welded to the T-ring joining the nose section to the barrel section and at the No. 7 ring a weld fixture is made to the extruded ring frame joining the barrel and dome sections. From here the eighth ring extends the slosh baffle 89.6 cm back into the dome area.

A 4.3 m long lance is attached to four A-frame supports in the interior of the forward ogive nose section, carrying a vent tube for the tumble system and temperature sensors. The completed LO_2 Tank weighs 5,646.8 kg, contains 606,739 kg of propellant and has a usable internal volume of 552.1 m^3.

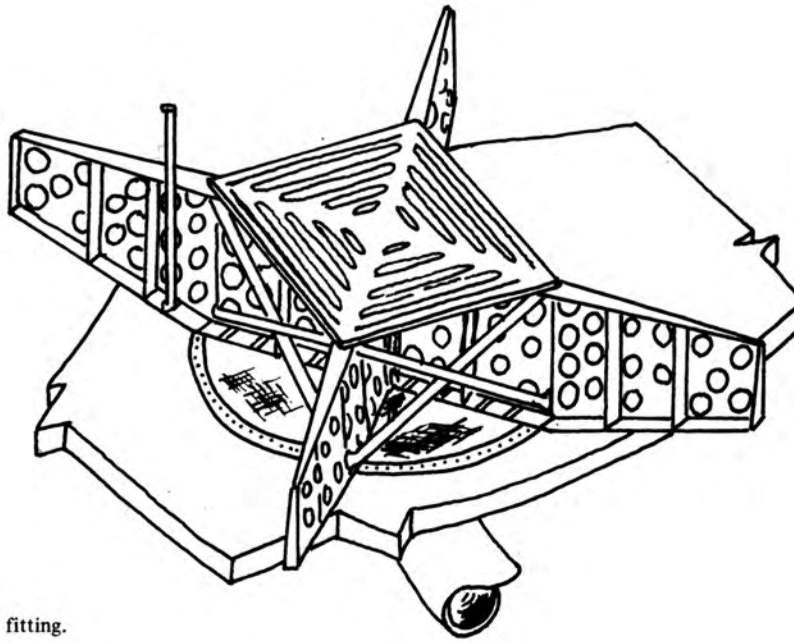


Fig. 4. LO_2 Tank anti-vortex baffle and inlet/outlet fitting.

LH_2 Tank

The liquid hydrogen tank, largest single propellant vessel yet designed for a launch vehicle, is a semi-monocoque fusion welded aluminium assembly comprising a forward dome, four barrel sections, five major ring frames, 13 intermediate rings, an aft dome, one antivortex baffle, two longerons and 12 attachment points for the Orbiter and two Solid Rocket Boosters (*note:* element interface hardware will be dealt with in a subsequent report). Internally the LH_2 Tank supports temperature and propellant quantity sensors and on the outside it carries the single LO_2 feedline, a GO_2 pressurisation line, a LO_2 antigeyser line and a cable tray. The completed assembly is 2,947.035 cm long with a maximum diameter of 840.74 cm, (Fig. 1).

The forward LH_2 tank dome is fabricated from aluminium 2219 in 12 gores with a central end-cap 3.55 m in diameter. The 0.75 ellipsoid shape is manufactured in the same manner as the 12 gore segments in the aft LO_2 tank dome with skin thickness varying from 0.17 cm to 0.22 cm and gore fusion butt weld areas 0.5 cm thick. The dome end-cap is generally 0.28 cm thick with provision for primary and auxiliary vent valve fittings, a GH_2 pressurisation line, an electrical feed-through and an access manhole similar to that in the LO_2 tank dome.

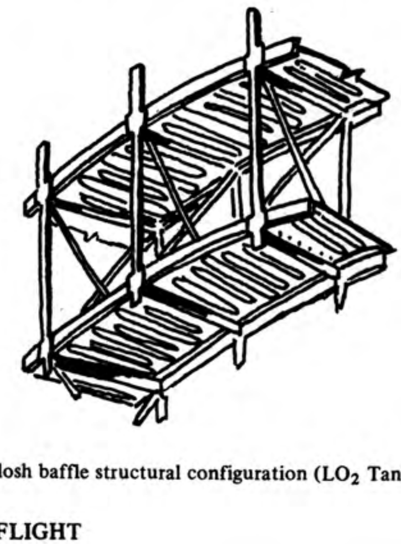


Fig. 5. Slosh baffle structural configuration (LO_2 Tank).

The four barrel sections form the main constant-diameter tank structure. Together they construct a cylinder 2,357.4 cm long with a diameter of 840.74 cm. Each barrel section is a fusion welded assembly of machined aluminium 2219 plate in eight pre-formed sections varying in thickness from 0.2 cm to 0.86 cm according to local loads. Barrel No. 1 at the forward end of the structure is 628.5 cm long with barrels 2, 3 and 4 626 cm, 627.9 cm and 475 cm long respectively and each barrel section is integrally machined with 96 longitudinal stringers. Each of the eight panel sections per barrel has an edge thickness of 0.86 cm to provide a weld face.

The four barrel sections also support a total of 13 intermediate Z-section ring frames attached to the cylindrical walls with three in barrel 1, three in barrel 2, four in barrel 3 and three in barrel 4. The extreme rear ring frame in barrel 4 stands 9.9 cm proud of the interior circumference and the extreme forward ring in barrel 4, and all four rings in barrel 3 are 6.85 cm wide. The remaining six rings in barrels 1 and 2 are 5.7 cm wide and all 12 rings so detailed are fabricated from four 90° extruded aluminium 2024 segments. The remaining intermediate ring, located between the fore and aft Z-section rings in barrel 4, is a webb-stiffened channel frame structure 25.4 cm wide to accommodate increased loads in this area.

The five major ring frames are fitted between the forward dome and barrel 1, between the four barrel sections and between barrel 5 and the aft dome. All the major ring frames are I-section beams fabricated in 90° segments from aluminium 2024 plate and sheet with 2219 and 2024 extrusions in a variety of chord and depth configurations.

The forward major ring frame is 25.4 cm deep at the bottom and 55.2 cm deep at the top where machined web fittings support the ET/Orbiter forward attachment bipod (see Fig. 1). The major ring frames between barrel sections 1 and 2 and 2 and 3 are similar I-section beams with a constant depth of 15.2 cm, locally stiffened in web and chord to accommodate LO_2 feedline support brackets. The major ring frame located between barrels 3 and 4 is a constant 50.8 cm in depth stiffened in web and chord to accept Orbiter thrust loads transferred to the frame by machined

fittings. This frame supports the forward left and right aft Orbiter attachment struts. The aft major ring frame between barrel 4 and the aft dome varies in chord and web to accept Orbiter and SRB induced loads. It carries the rear left and right aft Orbiter attachment struts and the aft upper and aft lower SRB attachment points. All five major ring frames are stabilised by stiffeners tied to the barrel stringers.

Two longerons fabricated from aluminium 2219 forgings are exterior welded to the skin panels of barrel 4 between the major ring frames forward and aft. They are 451.5 cm long and 83 cm wide placed 101.25° apart on the top of the External Tank. The forward area of the longerons (directly over the major ring frame between barrels 3 and 4) supports the forward left and right aft Orbiter attachment points and the rear area of the longerons (over the aft major ring frame between barrel 4 and the aft dome) supports bolt flanges for the rear left and rear right aft Orbiter fittings.

The aft tank dome is the same ellipsoidal shape, and fabricated from the same materials, as the forward LH_2 dome and the LO_2 tank dome with 12 gore segments and a 3.55 m diameter dome cap. The cap carries a LH_2 feedline fitting on the interior displaced 8° from the centre, a manhole for access to the feedline screen (similarly displaced by 8°) and a manhole for tank access. All manholes are standardised.

The LH_2 tank aft dome cap supports a 152 cm diameter siphon inlet support which contains a 116.8 cm diameter screen secured by 72 0.8 cm bolts, (Fig. 6). This contours from a 152 cm diameter to a 43.2 cm I.D. internal bellows feedline pipe angled over to pass through one of the 12 gore segments in the ellipsoidal aft dome adjacent to the aft major ring frame and connect with an external feedline pipe which takes propellant to the Orbiter interface.

An antivortex baffle (Fig. 6) is mounted on the internal face of the aft dome attached to a flange 83.8 cm above the siphon inlet support. It takes the form of four plates placed at 90° intervals with a total of 88 holes to reduce weight and damp local vortex flow patterns. Opposing plates span a width of 4.39 m. The baffle carries a quantity sensor arm, four channel brackets for depletion sensors and another quantity sensor is attached to the adjacent major ring frame. Other level sensors are secured to a channel in the forward dome and the forward major ring frame.

The LH_2 tank weighs 14,451.7 kg empty and its internal volume of 1,573.2 m^3 can contain 102,517.7 kg of propellant for a total weight of 116,969.4 kg. This is the largest tank structure fabricated for a launch vehicle, exceeding the internal volume of the LO_2 tank in the S-IC, first stage of the Saturn V and formerly the most voluminous by a handsome margin. The LH_2 tank in the Saturn V S-II second stage, formerly the largest liquid hydrogen launch vehicle tank, carried a maximum 72,674 kg of propellant or just 79% of the LH_2 tank in the Shuttle ET.

Intertank

The Intertank structure is a mechanical assembly of six skin panels, two thrust panels, five ring frames, four longerons and one SRB thrust beam, (Fig. 1). Provided for the purpose of separating the LO_2 and LH_2 tanks it is stressed to carry the left and right ET/SRB forward thrust attachment points, the only interface attachments not carried on the LH_2 Tank. The Intertank is 686.9 cm long with a skin diameter of 838.2 cm.

The main barrel of the Intertank is formed from two thrust panels 180° apart to left and right of the ET longitudinal axis and six stiffened panels welded together with forward and aft flanges for securing the assembly to LO_2 and LH_2 tanks respectively, (Fig. 7). The thrust panels are designed to carry axial SRB loads and provide cut-outs so that the SRB beam ends can protrude through the skin. They are 5.23 x 330.2 x 688.34 cm panels machined from

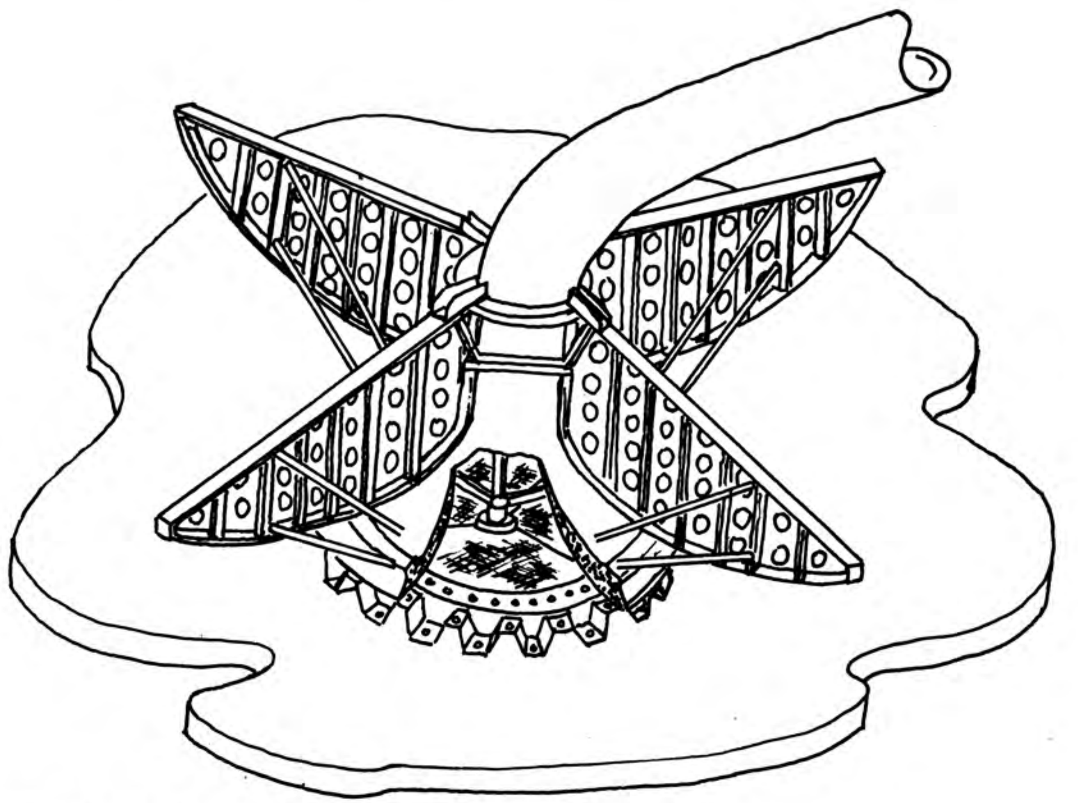


Fig. 6. LH_2 Tank anti-vortex baffle and feedline assembly

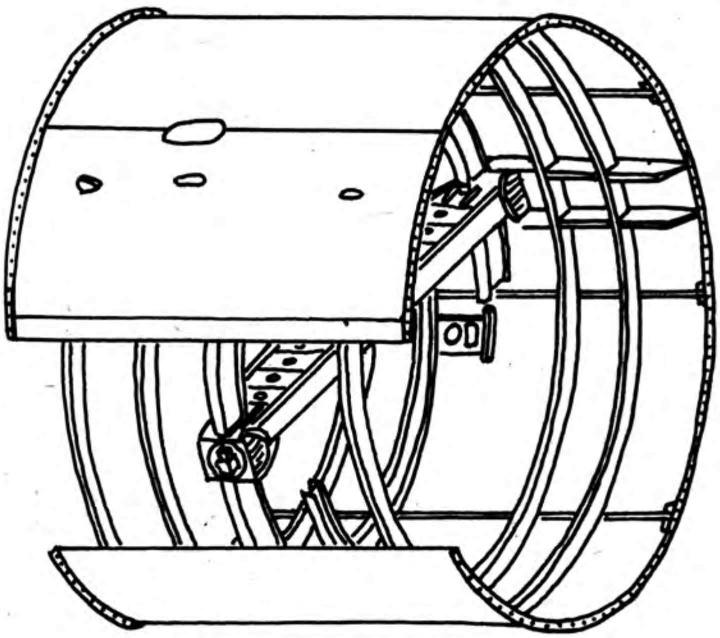


Fig. 7. Intertank assembly with thrust panel cut away to show SRB thrust beam.

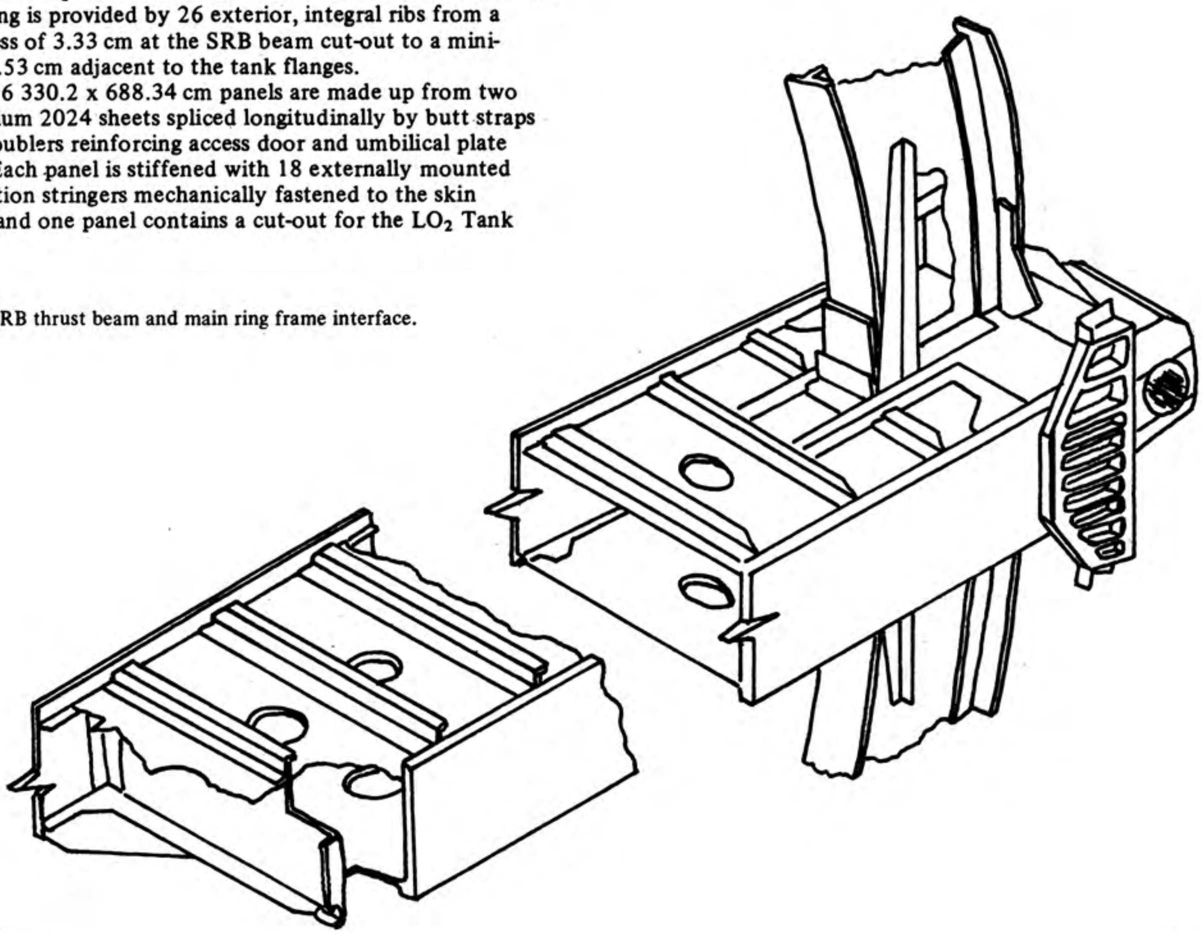
aluminium 2219 plate stock and formed into sections with a curved radius of 419.1 cm and then flanged at each end. Maximum thickness at the flanges is 1 cm and a minimum of 0.34 cm is provided in areas of low stress. Flutter resistance stiffening is provided by 26 exterior, integral ribs from a thickness of 3.33 cm at the SRB beam cut-out to a minimum 0.53 cm adjacent to the tank flanges.

The 6 330.2 x 688.34 cm panels are made up from two aluminium 2024 sheets spliced longitudinally by butt straps with doublers reinforcing access door and umbilical plate areas. Each panel is stiffened with 18 externally mounted hat-section stringers mechanically fastened to the skin panels and one panel contains a cut-out for the LO_2 Tank feedline and the anigeyser line which enter the Intertank volume from external sources. Two extruded I-beam reinforcements, 4.8 x 4.8 x 48.26 cm, are attached to locations adjacent to the LO_2 recirculation line entry points with a 4.8 x 7.6 x 101.6 cm I-beam at the umbilical plate.

The main ring frame is joined to the SRB beam and consists of 4 90° segments machined from 7075 aluminium joined to welds made up from seven spliced panels, (Fig. 8). The main ring frame is 50.8 cm deep and between 8.13 cm and 15.24 cm wide. It is situated nearly mid-way along the Intertank, exactly 337.5 cm from the forward, LO_2 Tank, attachment flange, (Fig. 7). The four intermediate frames are I-section beams 30.48 cm deep with a maximum width of 7.85 cm, two forward of the main ring frame and two aft. Assembled in 90° segments the ring frames are locally stiffened so as to accept openings, etc.

The SRB beam assembly (see Fig. 8) is built from top and bottom chords, stiffened webs, stability bulkheads and SRB thrust fittings all machined from aluminium 7075. The rectangular box beam is 876.3 cm between the SRB forward thrust fittings, 38.1 cm wide along its length, 66.04 cm deep at the interface with the main ring frame and 104.14 cm deep at the centre. It is designed to accommodate and transfer thrust loads from the two SRB assemblies to the ET and to provide a forward support interface for transportation pick-up points. Beam deflections during maximum acceleration, and a variety of potential situations such as asymetric SRB cut-off, necessitates beam clearances of 6.60 cm with the forward LO_2 Tank and 12.70 cm with the aft LH_2 Tank to accommodate forward and aft deflections of 4.06 cm and 10.16 cm respectively under the worst possible conditions and still leave a nominal

Fig. 8. SRB thrust beam and main ring frame interface.



2.54 cm clearance. The two SRB thrust fittings are machined from aluminium forgings and attached to the beam chords, webs and the main ring frame.

Two thrust panel longerons are fitted to the interior face of each thrust panel extending from the main ring frame forward to the LO_2 Tank attachment flange. They are each extruded hat-section 330.2 x 12.7 x 7.92 cm and provide stiffening against compressive loads applied to the thrust panels. Two pressure vent openings, each of elliptical shape 13.97 cm in the long axis and 3.5 cm in the minor axis, are situated in the forward end of the Intertank with vent tubes angled upward (when in the vertical position) so as to prevent rainwater entering the interior. An access door, attached to a 116.8 x 121.9 cm cut-out in a skin panel by 44 fasteners, is situated 146° in a clockwise direction from the top centre (when horizontal). The closed door protrudes to a line prescribed by the top of the external stiffeners and carries two inset handles. A flight umbilical plate is situated 120° in a clockwise direction from the ET top centreline and fabricated from aluminium plate stiffened with flanges and an external skin doubler.

The Intertank is secured to the forward LO_2 Tank by 194 1.4 cm bolts at the Intertank forward flange and LO_2 Tank aft ring frame interface. The rear flange of the Intertank is connected to the LH_2 Tank forward major ring frame with 178 1.4 cm bolts.

[To be continued

'NEW' LIFE FORM?

Biologists working for NASA and the National Science Foundation have identified a "new" form of life on Earth, possibly dating back to the planet's first one thousand million years.

The new form – previously thought to be a type of ordinary bacteria – is a methane-producing organism, representing a line of evolutionary descent that is totally separate from the two traditionally recognised lines, animals and plants, and bacteria. The organisms may be the oldest of life forms as well, coming not only before plants and animals, but also before bacteria.

The finding was made by a research team headed by Dr. Carl Woese, Professor of Genetics and Development at the University of Illinois, Urbana, an evolutionist and world expert on the genetic code. "The organisms are a distinct new class, no more related to typical bacteria than to higher forms," say the researchers. "They are a third form of life on this planet."

Methane-producing organisms appear to be ideally suited to what scientists believe to have been the Earth's primitive atmosphere:

- *They can get all their food and energy from very simple compounds such as carbon dioxide and hydrogen, the main gases in a primitive atmosphere.*
- *They do not use any of the complex chemicals most other organisms require as food, such as sugars and amino acids.*
- *Certain of the species grow best at high temperatures, in the range of 65-70 degrees Celsius (150-170 degrees Fahrenheit).*
- *They now can be found only in niches swept clean of oxygen, such as deep in hot springs at Yellowstone.*

The researchers said the discovery creates new hope that science will ultimately find out a great deal about how life came about on this planet, and so be in a better position to also understand and discover life forms that may have evolved elsewhere in the Solar System or beyond.

For a long time, many biologists have felt that all life on Earth came from a common ancestor. Over the past decade, a great deal of evidence supporting this view has accumulated. However, the nature of this common ancestor (except for its having to be quite simple) and the original branchings into the various lines of evolutionary descent were not known.

It is generally assumed that the two lines of descent that came from the common ancestor were represented by two basic types, the higher forms (animals and plants) and the lower forms (bacteria). That there might be a third form of life was an idea never seriously entertained by biologists.

For several decades, biologists have been working with a group of organisms that produce methane as their main waste product. But since the organisms are small, it had been taken for granted that they were ordinary bacteria. Until now, no one had suspected that these methane producers represented a line of descent from a common ancestor that is completely separate from the two traditionally recognised lines. (According to presently accepted ideas, the Earth, along with the Sun and the other planets, was formed about 4,600 million years ago. The earliest forms of life yet discovered on Earth – bacteria and simple plants – have been found in rocks laid down when the Earth was a thousand million years old or more. One thousand million years ago, wormlike creatures appeared, according to the fossil record, and 400 million years ago the first lungfishes emerged from stagnant ponds onto the land. From these descended the reptiles, and branches of the reptile family gave rise to dinosaurs, birds and mammals. The ancestors of modern man appeared approximately two million years ago).

Since the primaeval evolutionary branchings probably occurred during the first thousand million years of the Earth's existence, there is no hope of finding a fossil record of them. They occurred before the oldest rocks on Earth were formed. However, the living cell in a sense carries a partial record of its past in its genes. And over the past two decades, scientists have developed ways of partially deciphering these ancient genetic texts. (The measurement is actually done by determining how different from one another two "versions" of the same "test" are; the greater their difference, the further back their respective lines of descent separated from each other).

Through analysis of a particular very ancient and highly conserved portion of this genetic record, known as ribosomal RNA, they have been able to uncover evidence of events that occurred when the Earth was still relatively young – during the first thousand million years of its existence. By this means, the genealogy of the methane-producing organisms was shown to be distinct from both the typical bacterial and the animal-plant genealogies.

Three to four thousand million years ago, the Earth's atmosphere contained no oxygen. Instead it is thought to have been rich in carbon dioxide, hydrogen and other gases.

BRITAIN'S MILITARY SATELLITE

By Ian Hayes

Introduction

What goes 22,000 miles up into space and can travel between Britain and Hong Kong in a third of a second? The answer is a signal transmitted by the Skynet communications satellite system which has its UK terminal at RAF Oakhanger, near Alton.

Sited deep in the Hampshire countryside Oakhanger is one of the RAF's smallest stations with only 150 officers and men, but it is a key link in the worldwide communications chain used by all three British Forces.

The Skynet Satellite

The Skynet satellite is a drum shaped amplifier in orbit 22,000 miles above the Indian Ocean. It measures six feet by five feet and its receiving and transmitting equipment works off solar cells powered by the Sun. It has batteries for use in darkness.

There are three fixed Earth Stations in the Skynet chain situated at Oakhanger, Cyprus and Hong Kong. A handful of additional stations have been installed aboard Royal Navy ships. Until recent defence cuts the Army had two portable Skynet stations which could be deployed rapidly by air for use in the field.

The Skynet system provides virtually instantaneous communications between the Ministry of Defence in London and British land based forces or warships anywhere in the world. The system was particularly useful during the Cod War. The station commander Squadron Leader Roger Payne said: "Although hundreds of signals pass through Oakhanger every day the only ones we see are the few that specifically concern our unit. "When a unit in Cyprus or Hong Kong send a signal it is written out, given a priority and security classification and passed to a communications centre where it is converted onto a teleprinter message tape. "The holes in the tape are then converted into electrical signals which are bounced off the satellite and then put back onto tape at Oakhanger. From here the signals are passed on by landline to a communications centre at Stansbridge which in turn relays them to their destination.

"The highest priority signals, known as flash messages, deal with matters of operational urgency. They can be written out, processed, transmitted round the world and translated back into written messages within 15 minutes.

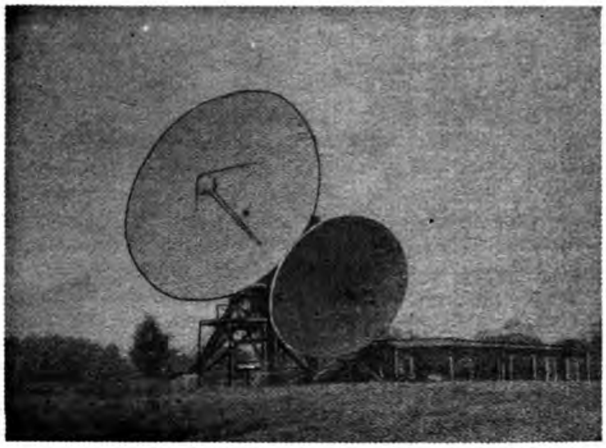
"Other signals have various classifications according to their urgency. The lowest speed priority is given to routine matters such as inspections and VIP visits".

The units at Oakhanger are dispersed over five separate sites. The main communications centre controls all the signals which pass through the satellite between the UK, Cyprus and Hong Kong and the naval stations afloat.

These signals pass between Oakhanger's mass of transmitting and receiving equipment and the satellite through a 40 ft. dish aerial. A part of this station is the Master Engineering Control centre which controls the Skynet communications channels and issues appropriate instructions through the satellite to the other Earth Stations. From here the system is monitored continuously to ensure the high quality operation of the whole network. Any malfunction is instantly detected and pinpointed. There are 29 warning buzzers and bells in the centre.

The Telemetry and Command Station with its 60 ft. high dish aerial monitors the health of the satellite itself and controls it. The station constantly keeps track of the satellite's position, temperature and voltage.

It can diagnose any faults which may develop, and, in many instances, take remedial action. The station also adjusts the satellite's position in space to maintain its orbit.



Skynet communications antennae at RAF Oakhanger, near Alton, Hampshire, England.

RAF Official Photograph: Crown copyright reserved

Should the need arise the station can move it to some other point over the equator within this orbit. The satellite can be "seen" simultaneously by the stations in the UK, Cyprus and Hong Kong.

Also at Oakhanger is an RAF manned NATO Satellite Ground Terminal Unit which is a separate entity handling signals traffic from an American satellite over the Atlantic. All three stations operate continuously and are manned for 24 hours on every day of the year.

Another important part of the Oakhanger complex is the RAF's only satellite communications training school. It has an instructional staff of three NCO's and provides specialist post graduate training for technicians posted to Oakhanger and the stations in Cyprus and Hong Kong.

Ground communications fitters and radar fitters do a 10 week course at the school which also provides familiarisation training for officers and Navy personnel. On the same site is a servicing centre which repairs equipment throughout the Skynet system.

The three Services long range strategic communications systems were amalgamated in 1966 into one worldwide organisation known as the Defence Communications Network.

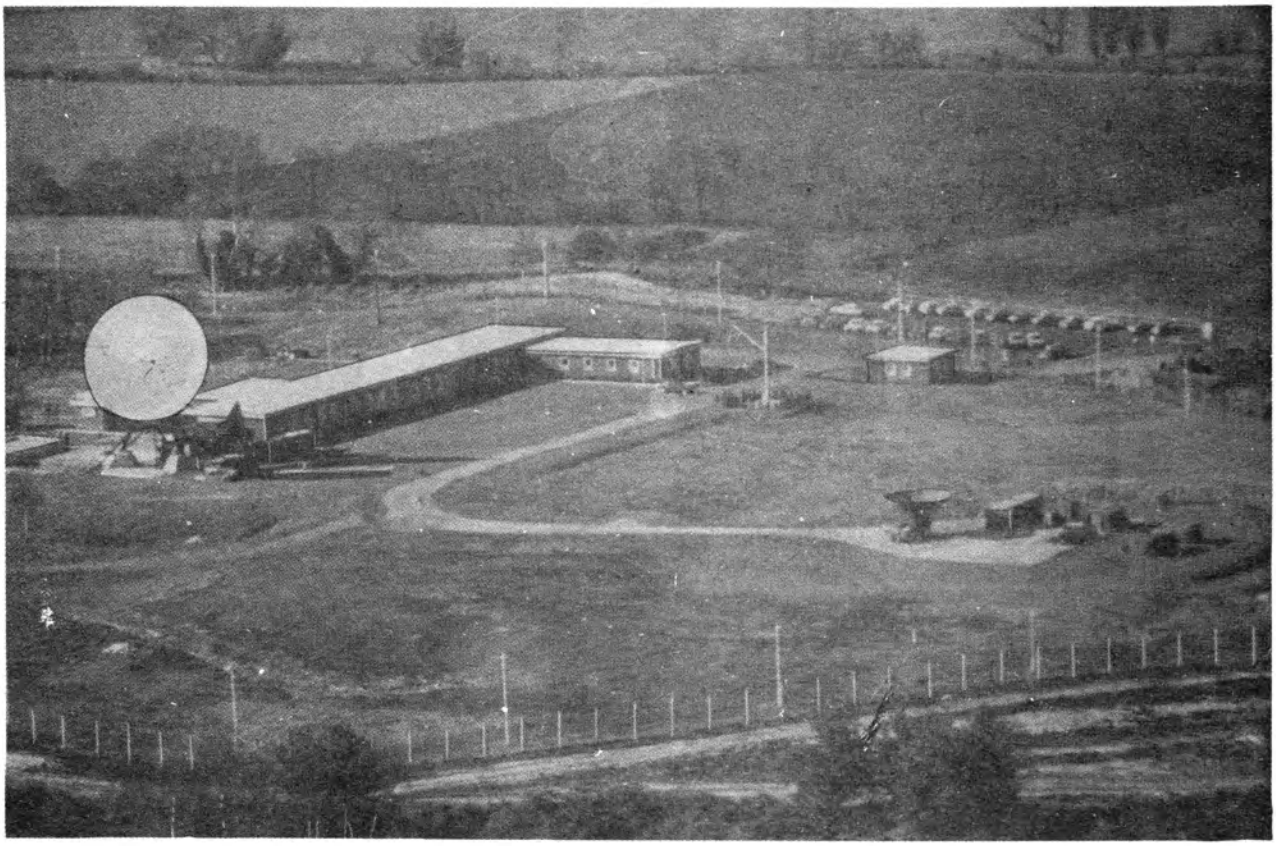
The RAF went into space communications in 1969 and the first officers and airmen of No. 1001 Signals Unit arrived at Oakhanger in February of that year. There had previously been a US Navy unit at Oakhanger whose function was to bounce signals off the Moon.

Skynet One was launched by an American Thor Delta rocket from Cape Canaveral on 22 November 1969. Control of the satellite was formerly handed over to the Telemetry and Command station at Oakhanger on 16 February 1970.

The first operational signals traffic was passed over the Skynet system in April 1971. Skynet One came to the end of its useful life in 1972 and the Skynet Earth Stations transferred operations onto US satellites.

During 1972 the Telemetry and Command Station was taken out of service for seven months for a major modification to enable it to operate Skynet Two. This satellite was launched in the USA in January 1974 but the launch rocket failed to achieve its final orbit.

The second launch of Skynet Two took place in November



Aerial view of RAF Oakhanger in the Hampshire countryside. *RAF Official Photograph. Crown copyright reserved*

1974 with a Delta rocket. It was entirely successful.

A team from RAF Oakhanger visited the USA to help with the launch preparations and the initial orbit operations. The Skynet Two satellite was entrusted to the control of the TCS at Oakhanger in December 1974 and became fully operational in January 1975.

Each Skynet satellite has a planned useful life of three years. However, in the present climate of Defence cuts there is unlikely to be another British satellite launched in the foreseeable future.

When Skynet Two wears out the Earth Stations will have to use American satellites. There was Skynet Earth Stations in Bahrein, Gan and Singapore before British Forces left these areas.

The Singapore station was moved to Hong Kong and the equipment from Bahrein and Gan was used to increase the capacity of the Hong Kong and Cyprus stations. Initially the Royal Navy's Skynet stations were installed aboard the assault ships *Fearless* and *Intrepid.*

The systems have since been installed aboard ships of down to frigate size and Skynet was used operationally during the Cod War. Skynet stations have also been installed aboard aircraft and Commando carriers.

In Skynet Britain's forces have a communications system directly under British control. The satellite was specially designed to meet stringent British requirements for communicating to large and small stations simultaneously.

Communications which pass through the satellite are precisely focused towards Earth by an automatically controlled aerial. To ensure reliability interchangeable duplicate reequipment can be brought into use at RAF Oakhanger.

Summing up the advantages of the system Squadron Leader Payne said: "It is far more flexible and has greater capacity than previous communications systems. It is free from the ionospheric effects which interrupt high frequency radio circuits on which most long distance defence communications previously depended".

In addition to providing satellite communications for the RAF, Army and Royal Navy, Oakhanger handles signals traffic for US Navy ships and shore stations. Its role is summed up by the station's badge which depicts the winged helmet of Mercury, messenger of the gods and the motto "I speak beyond the Earth".

BIS FELLOWSHIP EXAMINATION

The Council is pleased to announce that the following candidates passed the Section II written examination held in June 1977:

T. R. C. Hassell **D. J. Richer**

I. G. MacKinlay **J. R. Ware**

The assistance provided by the Waikato Technical Institute, Hamilton, New Zealand in acting as a local examination centre is gratefully acknowledged.

Details of BIS Study Courses and the Syllabus and Regulations of the Fellowship Examination may be obtained from the Executive Secretary.

NAMES OF US MANNED SPACECRAFT

By Curtis Peebles

Introduction

In the history of the US space programme, the subject of spacecraft names has been a strange chapter. It is a very human side of this century's greatest technical triumph. The names and patch designs express the crews' personal preferences. Unlike the Russians, there was no pattern to the names [1]. This article seeks to catalogue these names, their origins and meanings.

Mercury

The first US space mission was named Freedom 7 by its Commander, Alan Shepard. He considered it his prerogative to name the spacecraft; after all, pilots had been naming their aircraft for years. The 7 was the capsule's factory number but all Mercury capsules carried a 7 to symbolise the 7 astronauts.

The next mission was Gus Grissom's Liberty Bell 7, so named because that's what the capsule looked like. After splashdown, its hatch prematurely blew off, sinking the capsule. Grissom escaped but the accident would have an unexpected side effect years later.

The name for the first US orbital mission involved a very careful selection. Glenn set his family to work selecting names. He finally decided on Friendship 7 because it expressed the spirit he wanted to convey.

Aurora 7 was selected by Carpenter because of its celestial significance and for sentimental reasons. It was his old childhood address.

Schirra's Signa 7 stood for the "sum of many parts". The last Mercury mission, Faith 7, again expressed the spirit Cooper wanted.

Project Mercury

Mission	*Name*
Mercury 3	Freedom 7
Mercury 4	Liberty Bell 7
Mercury 6	Friendship 7
Mercury 7	Aurora 7
Mercury 8	Sigma 7
Mercury 9	Faith 7

The Battle

Grissom, the Commander of the first Gemini mission, had, in the meantime, been giving careful thought to names and to his lost capsule. He finally decided to call Gemini 3 "The Molly Brown" after the play "The Unsinkable Molly Brown". This bit of humour was lost on the NASA bureaucracy. A directive was issued forbidding names. NASA was concerned about its image and humour didn't quite fit in. Grissom was, in the end, triumphant. "Molly Brown" was used in all communications throughout the mission.

The next two crews were less successful. Gemini 4 and 5 did not go down in history as "American Eagle" and "Lady Bird". The Gemini 5 crew was, however, the first to design a personal mission patch even though they had to fight for it. The patch had the crew names, a covered wagon with the slogan "8 days or bust" on it.

These patches became the symbols of the mission and considerable effort went into their design: the marathon nature of Gemini 7, the spectrum of task of Gemini 8,

Project Gemini

Gemini 3	Molly Brown
Gemini 4	American Eagle (not used)
Gemini 5	Lady Bird (not used)
Gemini 6 through 12	no name

Cernan's walk in space aboard Gemini 9 and the all navy crew and the high orbit they were to achieve in Gemini 11.

Apollo

The Apollo 1 patch had the stars and stripes as the outer rim; the crew's names, the Earth, spacecraft and the Moon in the centre but fate deemed it would never fly. Schirra, Eisele and Cunningham, the Apollo 7 crew, briefly considered a Phoenix bird as their mission patch but a Phoenix arising from the ashes of the fire which had consumed it, was perhaps too symbolic [2].

It was the Apollo system itself which forced a policy change. All missions after Apollo 8* would involve the Lunar Module. To avoid confusion, during separate operations, each spacecraft needed a call sign. The first two were "Gumdrop" (CSM) and "Spider" (LM) of Apollo 9. Spider was particularly appropriate as the LM looked like some other worldy creature.

To prove humour had won out, Apollo 10 (CSM/LM) was "Charlie Brown" and "Snoopy", named after characters in the "Peanuts" comic strip.

The Apollo 11 crew considered using paired names; "Romeo-Juliet", etc., but, in the end, this was rejected. The name of the LM, "Eagle", came from the mission patch. The CSM was named Columbia after the spacecraft in Jules Verne's "From the Earth to the Moon".

A great deal of effort went into the patch design. The Apollo 11 crew wanted something simple, but direct, which expressed Apollo's peaceful conquest of the Moon and of all the people who made the dream come true. It was Jim Lovell who suggested the Eagle and Mike Collins who prepared the original design. NASA approved after the addition of the olive branch.

Charles Conrad, Apollo 12 Commander, selected Intrepid for the Lunar Module. The CSM became the "Yankee Clipper", appropriate for an all-navy crew. On the patch were four stars, three for the crew members and one for C. C. Williams, the original Lunar Module pilot who was killed in a 1967 plane crash. Alan Bean, his replacement, suggested it [4].

For Apollo 13, the crew reached into American mythology; "Odyssey" (CSM) was in honour of "2001 A Space Odyssey". Aquarius (LM) was the sign of the Zodiac, popularised in a song title.

Apollo 14, CSM was "Kitty Hawk" after the location of the first powered aircraft flight. The LM was Antares, a star used for navigation during the mission. For the all Air Force crew of Apollo 15, the name of the LM came easy – Falcon, the Air Force Academy mascot. The CSM was named Endeavour after Captain Cook's ship.

* *Jim Lovell wanted to name the Saturn V booster, on this mission, Columbiad, after Jules Verne's very similar mission [3].*

Apollo 16 (CSM) was "Casper"* (another cartoon character). The Lunar Module was Orion (a constellation, the Hunter); appropriate as it carried a small ultra-violet telescope which would take the first astronomical photos from the Moon.

Apollo 17, which closed out the first generation of lunar exploration, was named "America" (CSM) and "Challenger", (LM) after the *HMS Challenger* which laid the foundation for modern oceanography 100 years before [6]. On the patch, was a classic statue of Apollo; behind it was a stylised American Eagle and in the distance was the Moon, Saturn and a Galaxy. Though it was the last Apollo, it was not the end of man's exploring. The CSM's, for the three Skylab missions and the ASTP flight, were once more nameless.

Project Apollo

Apollo 1	no name
Apollo 7	no name
Apollo 8	Columbiad (not used)
Apollo 9	Gumdrop (CM) Spider (LM)
Apollo 10	Charlie Brown (CM) Snoopy (LM)
Apollo 11	Columbia (CM) Eagle (LM)
Apollo 12	Yankee Clipper (CM) Intrepid (LM)
Apollo 13	Odyssey (CM) Aquarius (LM)
Apollo 14	Kitty Hawk (CM) Antares (LM)
Apollo 15	Endeavor (CM) Falcon (LM)
Apollo 16	Casper (CM) Orion (LM)
Apollo 17	America (CM) Challenger (LM)

Project Skylab

Skylab 1 through 3	no name

Apollo-Soyuz Test Project

Apollo 18	no name

Space Shuttle

Orbiter 101	Enterprise
Orbiters 102 through 105 have not yet been named	

* *Casper (a ghost) was chosen by Mattingly because astronauts, on the Moon, looked like apparitions [5].*

Space, the Final Frontier

By the late spring of 1976, NASA had decided to give each individual shuttle a name. The first, Orbiter 101, would be the "Constitution" because 17 September, the day of the roll-out, was Constitution Day.

At this time, a letter writing campaign began requesting that Orbiter 101 be given a name which not only was a part of America's past but its future as well. A name carried by eight US naval vessels and a starship – Star Trek's "Enterprise". All through the summer, the letters and petitions from the series' fans were sent to the White House. The final total was nearly 100,000 signatures [7].

NASA was divided on the issue. One group was concerned about the commercial aspects of the show; the other believed that the name would give the Shuttle instant recognition.

On 6 September, Dr. James C. Fletcher, NASA Administrator, who had served aboard the World War II carrier, *Enterprise,* and later admitted a certain partiality for the name, met with President Gerald R. Ford to discuss the Viking missions, other NASA activities and the naming of the Shuttle. The President selected "Enterprise" over several others that NASA had provided [8].

Conclusion

At present, Space Shuttles 102 through 105 are nameless. Presumably, one will be named "Constitution" as both "Enterprise" and "Constitution" are from US naval history. It is to be expected the remaining Shuttle will continue this procedure.

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8. *Aviation Week and Space Technology,* 13 September 1976.

GERMANY JOINS JUPITER GROUP

The Federal Republic of Germany has taken another major step in interplanetary exploration by agreeing to participate in NASA's 1982 Jupiter Orbiter Probe (JOP) mission. Scheduled to become the first planetary spacecraft to be carried aboard the Space Shuttle, JOP is designed to conduct the most detailed scientific investigation yet of Jupiter, its environment and moons, including the first measurements of the planet's atmosphere.

The mission is composed of an orbiter which will circle the planet for at least 20 months and a probe which will plunge deeply into Jupiter's atmosphere. Under the agreement, BMFT will provide a Retro Propulsion Module designed for injection of the JOP spacecraft into orbit around Jupiter. It also will provide selected scientific instruments for integration into the scientific payload and the services of selected scientific investigators.

This cooperation with Germany carries forward a relationship established in the NASA/BMFT cooperative probes to the vicinity of the Sun carried out in 1975 and 1976 (Project Helios).

The JOP team will be composed of 114 scientific investigators, including 14 Germans. The orbiter will carry 10 instruments, and the probe will carry six. German scientists will be involved in the preparation and operation of both spacecraft and in the analysis of resulting data.

SPACEMEN IN THE WET

By Dave Dooling

Engineers at Marshall Space Flight Center are getting their feet wet in the new art of assembling large structures in space. The neutral bouyancy simulator – after several months of refurbishment – is again in use as MSFC prepares for the Space Shuttle and its extra vehicular activities (EVA).

"Now we're beginning to get to the point in some of these programmes where they need evaluation in the NBS," said Charles Cooper, who is in charge of the tank.

"We have several Spacelab EVA-type activities when we're using suits." The tank is 75 ft. (22.8 m) wide and 40 ft. (12.2 m) deep.

The 1-million-gallon tank was drained in November 1976, refurbished and refilled. New experiments include assembly of space trusses, moving large masses and a flying platform.

Presently, the tank is set up with a "corridor" made of white nylon line. In the middle sits a simulated nine-ton mass.

"We are attempting to move various masses down that corridor to determine how much mass a man can move accurately," Cooper said. The mass is a bundle of water-filled plastic canisters in a circular frame. It is neutrally bouyant – neither floating nor sinking – but because the water is trapped inside the canisters, moving it is the same as moving 18,000 lb. (8,165 kg) in zero-gravity.

"It's really a very basic experiment that has nothing to do with Shuttle," Cooper said. However, the experiment will influence designs for large space structures, such as power stations. One recent experiment along that line involved the assembly of a metal triangle – 15 ft. (4.57 m) on each side – by an astronaut and a remote manipulator arm. The Shuttle will have a remote arm and is expected to conduct assembly experiments. The triangle was assembled on a half cylinder the same width as the Shuttle cargo box.

In recent tests, Skylab astronaut Paul Weitz worked with a Spacelab mockup to see if the pressure module airlock hatch can be jettisoned from the outside. In the event it is jammed open, the Shuttle payload bay doors cannot be closed, and the Shuttle cannot return to Earth.

As with other tank tests, MSFC engineers developed what they believed to be a workable procedure, then brought in an astronaut for the acid test.

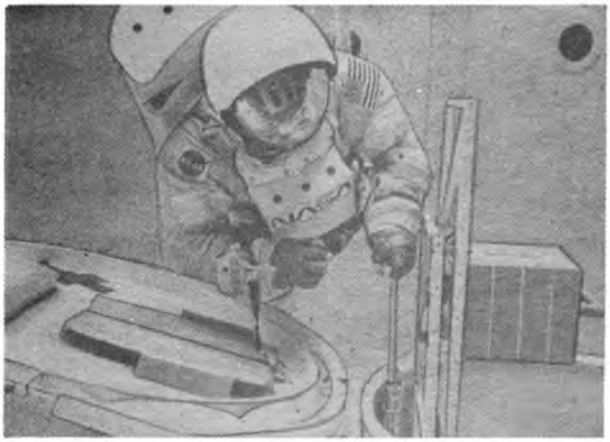
The water tank was the scene of intense activity during Skylab in 1973 as engineers tried to improvise ways to save the three-man space station when it lost its thermal shield. The tank, in use since 1968, went into a round-the-clock operation until procedures were worked out for extending a stuck solar power unit and for spreading a special sunshade.

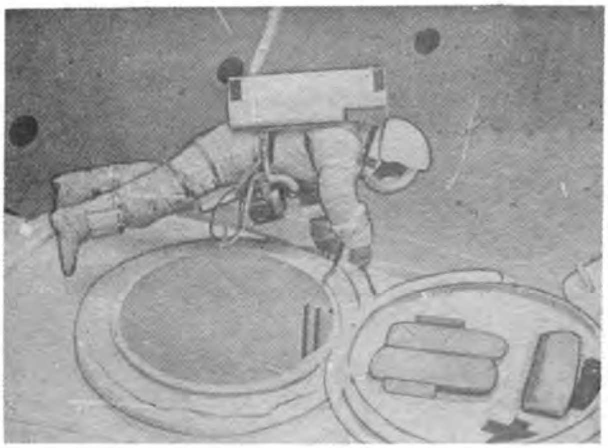
"From a flight management standpoint," Cooper said, "the NBS was a great risk assessment too." With it, astronauts were able to test and verify EVA routines the crews in space had not trained for.

The tank also has had some distinguished visitors in it, including the late Dr. Wernher von Braun (while he was MSFC director), Dr. George Mueller (a former associate administrator of NASA), Hugh O'Brian (for a movie he was making), and Soviet cosmonaut Vitaly Sevastyanov (a two-time space veteran).

One of the discoveries from the Skylab era was that astronauts need extra training in the tank. Cooper said MSFC engineers would design equipment and test in the tank, only to redesign it because the astronauts could not do the identical task.

This was partly because the engineers also were the designers, "a considerably unfair advantage over the astronaut." But the astronauts also lacked tank time.





Astronaut Paul Weitz works with a Spacelab mockup in the base of the Neutral Bouyancy Simulator at the Marshall Space Flight Center, Huntsville, Alabama. He is experimenting with the airlock hatch.

National Aeronautics and Space Administration

"At no time has he had any opportunity to spend a lot of time in a suit in a weightless condition," Cooper said. A person needs about 10 to 20 hours to learn how to pace himself before mastering the technique.

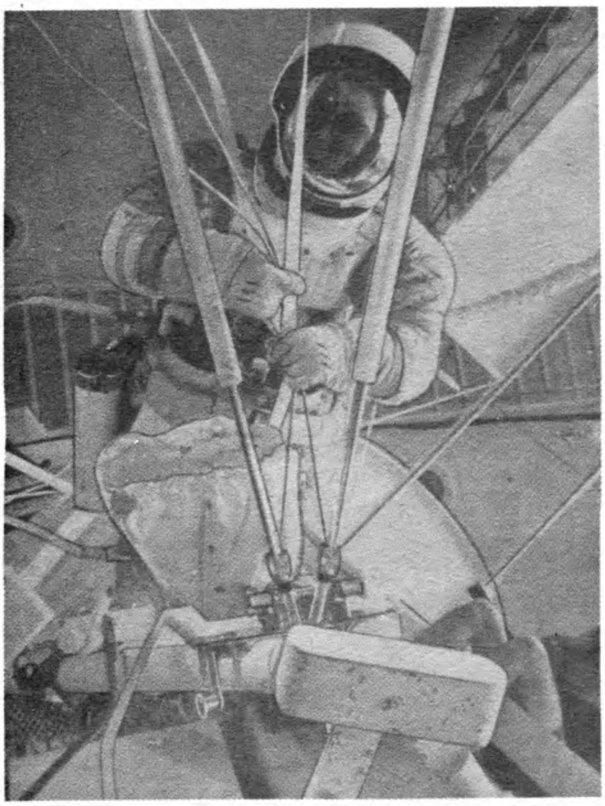
Four to eight underwater television cameras are used to record every movement of test technicians or astronauts. Later, both image and sound can be played back to examine what worked and what did not.

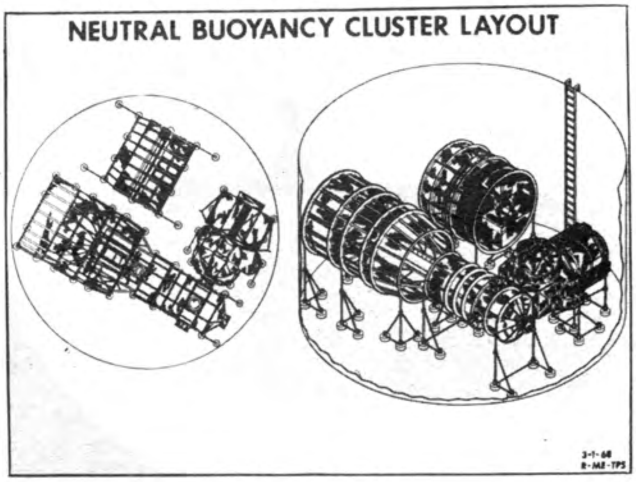
Cooper is one of about 12 engineers and technicians at MSFC who is qualified to wear a space suit in the tank. Another dozen divers assist the suited test subjects or act as underwater lifeguards.

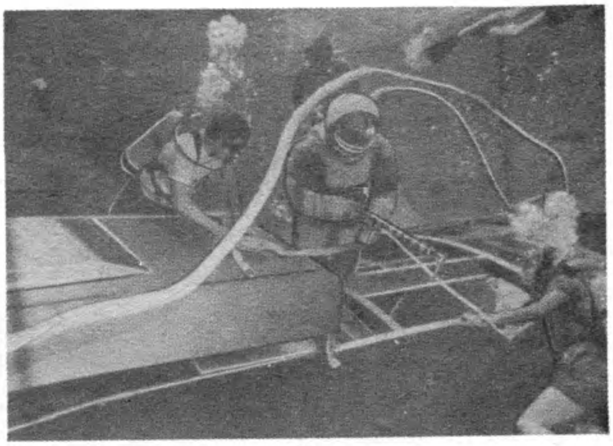
To use a space suit in the tank, Cooper said, a person must be qualified as a scuba diver, checked out in a pressure suit, then qualified to use the pressure suit underwater.

All his divers are trained in first aid; most can operate the recompression chamber and six are trained as emergency medical technicians.

Even though the tank is shallow, a diver still can catch the bends, a painful ailment caused by nitrogen boiling out of the blood when a diver ascends too fast. This can be fatal in extreme cases, but Cooper says there has been only one minor case at the tank. That was cured by taking the man back down and bringing him up slowly.







Above, in May 1973 NASA engineers were busy in the tank working out methods to salvage the badly damaged Skylab space station. The twin-pole shield was one concept under consideration by NASA as a means of providing solar protection following loss of the station's meteoroid shield. *Top right,* how mockups of the original Saturn 1 workshop were laid out in the tank. The frame and mesh mockups were full-scale models of the Saturn 1 Workshop, Multiple Docking Adapter and Apollo Telescope Mount. *Right Below,* engineer Charles Cooper of the Marshall Center works with a 'shepherd's hook' repair tool for the Skylab space station in orbit. Surrounding him in the tank are safety divers. The underwater simulations allowed astronauts to fly to the damaged station with cutting and prying tools with which they eventually freed the station's remaining solar 'wing.'

National Aeronautics and Space Administration

The bends is more of a problem for whomever is in the space suit. In order for the simulation to be effective, Cooper said, the suit pressure must be greater (by 3.7 pounds per square inch) than the surrounding water, just as suit pressure in space is greater than the surrounding vaccum. This adds about 10 ft. (3.05 m) to the working depth. Dive times are usually limited to three hours to keep the blood from becoming saturated with gas.

Working in zero-gravity is not as easy as early science fiction stories predicted. It is exhausting work, as Gemini astronauts discovered. Simply because there is no friction as on Earth, just staying in one place is a major task.

"It's quite tiring because most of the work done is done by your hands or arms," Cooper said of his own simulation experience and comments by astronauts. "You tire out your ability to grip things pretty quickly."

But is the tank a fair simulation of the real thing?

"The standard comment by the flight crews is that if you can do it in the tank, you can do it in space, Cooper said. He added that one Skylab crewman while retrieving a film magazine outside the orbiting workshop, looked at the Earth and told mission control:

"Just like the tank – only farther to the bottom."

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Continued from opposite page]

(3) Interplanetary spacecraft investigating the outer planets, Voyager 2 will reach Jupiter in 1979 July, Saturn in 1981 August If Voyager 1 (launched 1977 September 5) is reasonably successful in its mission, Voyager 2 will continue to Uranus and Neptune. Because of the trajectories chosen, Voyager 1 will reach Jupiter about 4 months ahead of Voyager 2.
(4) Orbital data are at 1977 Aug 25.3 and 1977 Aug 25.5; a redundant manoeuvring engine was ejected from 1977-78A during 1977 Sep 5. It is designated 1977-78F.
(5) Italian experimental communications satellite, positioned at 15°W longitude.

Amendments and decays:
1977-72A, Cosmos 934 was recovered 1977 Aug 9.38, lifetime 12.62 days.
1977-73A, Cosmos 935 was recovered 1977 Aug 11.22, lifetime 12.88 days.
1976-121 A&B, Cosmos 881 and 882, delete footnote; the launch may be connected with the manned space programme, see Cosmos 929 (1977-66a) entry in last month's Digest.

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Continued from January issue, page 18]

A listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information sources include the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Novosti and both the popular and specialist press. For a more detailed summary, see Satellite Digest – 111, January, 1978.

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 936 1977-74A	1977 Aug 3.59 18.55 days (R) 1977 Aug 22.14	Cylinder + sphere + cylinder-cone 6000?	6 long? 2.2 dia?	219	396	62.80	90.63	Plesetsk A-2 USSR/USSR (1)
HEAO 1 1977-75A	1977 Aug 12.27 5 years	Octagonal cylinder 2720	5.8 long 2.4 dia	428	447	22.76	93.16	ETR Atlas-Centaur NASA/NASA (2)
Voyager 2 1977-76A	1977 Aug 20.60	Octagon + dish + booms 800	1.9 dia 1.5 high 3.7 dish		heliocentric orbit			ETR Titan 3-Centaur NASA/NASA (3)
Cosmos 937 1977-77A	1977 Aug 24.30 6 years?	Cylinder?		149 424	597 444	65.05 65.04	92.07 93.31	Plesetsk F-1-m USSR/USSR
Cosmos 938 1977-78A	1977 Aug 24.61 12.63 days (R) 1977 Sep 6.24	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	181 156	340 332	62.81 62.81	89.70 89.37	Plesetsk A-2 USSR/USSR (4)
Cosmos 939 1977-79A	1977 Aug 24.76 8000 years	Spheroid 40?	1.0 long? 0.8 dia?	1435	1464	74.02	114.88	Plesetsk C-1 USSR/USSR
Cosmos 940 1977-79B	1977 Aug 24.76 6000 years	Spheroid 40?	1.0 long? 0.8 dia?	1397	1464	74.02	114.46	Plesetsk C-1 USSR/USSR
Cosmos 941 1977-79C	1977 Aug 24.76 7000 years	Spheroid 40?	1.0 long? 0.8 dia?	1416	1464	74.02	114.67	Plesetsk C-1 USSR/USSR
Cosmos 942 1977-79D	1977 Aug 24.76 10 000 years	Spheroid 40?	1.0 long? 0.8 dia?	1464	1535	74.02	115.98	Plesetsk C-1 USSR/USSR
Cosmos 943 1977-79E	1977 Aug 24.76 9000 years	Spheroid 40?	1.0 long? 0.8 dia?	1453	1464	74.02	115.08	Plesetsk C-1 USSR/USSR
Cosmos 944 1977-79F	1977 Aug 24.76 9000 years	Spheroid 40?	1.0 long? 0.8 dia?	1464	1473	74.02	115.30	Plesetsk C-1 USSR/USSR
Cosmos 945 1977-79G	1977 Aug 24.76 10 000 years	Spheroid 40?	1.0 long? 0.8 dia?	1464	1493	74.02	115.52	Plesetsk C-1 USSR/USSR
Cosmos 946 1977-79H	1977 Aug 24.76 10 000 years	Spheroid 40?	1.0 long? 0.8 dia?	1464	1512	74.02	115.73	Plesetsk C-1 USSR/USSR
Sirio 1 1977-80A	1977 Aug 25.99 indefinite	Cylinder 220	2.0 long 1.4 dia	245 33653	37215 37208	22.96 0.24	659.92 1417.95	ETR Delta Italy/NASA (5)
Cosmos 947 1977-81A	1977 Aug 27.43 12.77 days (R) 1977 Sep 9.20	Sphere + cylinder-cone 5500?	5 long? 2.2 dia?	203	321	72.85	89.75	Plesetsk A-2 USSR/USSR

Supplementary notes:

(1) International biological satellite carrying experiments and equipment from the USSR, USA, Czechoslovakia and France. Other Eastern bloc countries taking part in post-flight analysis include Bulgaria, the GDR, Poland and Romania. A 2m diameter, 0.5m deep experiments package was ejected during 1977 Aug 21, it is designated 1977-74D.

(2) High Energy Astronomical Observatory designed to measure X-ray emissions. Launch was originally intended for 1977 Apr 15 but problems with the attitude control system forced a delay.

[Continued at foot of page 72

BOOK REVIEWS

Astronomy: Principles and Practice. 342 pp. £10.00 (£7.50 paperback).
Astronomy: Structure of the Universe. 284 pp. £10.00 (£7.50 paperback).
By. A. E. Roy and D. Clarke, Adam Hilger Ltd., 1977.

These two complementary volumes are intended 'to fulfil the need of a preliminary science course or a liberal arts course at the first year university level' – or for the serious amateur astronomer. The authors, both from the Department of Astronomy at Glasgow University, admit that much of the material is taken from lectures and practical work given in the first year course in their department, and as such it does, of course, admirably serve its purpose. As may be expected, a great deal of the information presented can be found elsewhere, but the usefulness of the volumes lies in the gathering together of the diverse topics into a reasonably compact and certainly readily understandable form. This latter requirement is essential as, for instance in the case of Glasgow University, the course attracts a certain number of arts students wishing to gain some insight of science and the scientific method. The authors feel that astronomy is, perhaps, the best branch of science for doing this – a sentiment with which I am in absolute agreement.

In *Principles and Practice* the text is divided into the following broad sections: (1) a brief introduction giving basic background information and definitions; (2) elementary celestial mechanics; (3) observational techniques and (4) a short chapter dealing with practical work. Under the heading of celestial mechanics there is a fairly standard treatment of spherical geometry, the celestial sphere and time-keeping systems. This is followed by chapters on positional astronomy and discussions of the two-body and many-body problems complete this section. 'Observational techniques' covers just those topics which one would expect, *viz* radiation and the means of collecting it in the visible and radio ranges (including relevant formulae and ray diagrams). Special optical systems such as Schmidt reflectors, the Maksutov-Bouwers camera and coronographs are mentioned as well as modern optical detectors,including photomultipliers and image intensifiers.

The second of the two volumes, *Structure of the Universe,* comprises sections broadly encompassing (1) the Solar System; (2) astrophysics and (3) galactic structure and cosmology. The first section, whilst covering aspects of planetary astronomy and the Sun, by necessity gives only fairly basic information and more detailed discussions must be sought elsewhere. Other features and bodies of the Solar System (such as meteors and comets) receive only brief acknowledgement. Indeed, as the Solar System is nowadays rather more the territory of the geologist, meteorologist and other previously terrestrial-bound scientists, it is arguable that such a section could have been omitted with little loss of purpose. The chapters relating to the very broad subject of astrophysics are introduced with a look at the raw observational data – measurements of stellar radiation – and the facts which may be deduced from these observations. This leads to discussions of stellar atmospheres and interiors, and stellar motions. Stars with special properties (e.g. Wolf-Rayet, variable, stars with extended atmospheres), nebulae (diffuse, supernovae remnants etc.) and more exotic objects such as quasars, pulsars, black holes and infra-red objects are examined, if only briefly. The third section deals with the structure of our Galaxy and others, and is concluded by a discussion of cosmology, cosmogony and even a very brief mention of life in the Universe!

In view of the obvious usefulness and aim of these two books, it seems a pity that their cost is so high – £20.00 for the hard-back versions or £15.00 for the paperback (although I imagine the latter editions could be a little unwieldy for such large format books). This seems expensive if they are intended for students or amateurs. Could this not have been reduced if more economic use had been made of the printing? After all, only some 2/3rds of most pages are actually printed upon, the remaining 1/3rd of each page usually forming a blank margin and only occasionally used for diagrams. More stringent publication arrangements could have much reduced the size of the volumes with no loss of quality to the text. However, this minor irritation in no way distracts from the value and authority of the books which will be much welcomed by University and other courses. The volumes are very well illustrated with photographs and line diagrams.

S. G. SYKES

Detection and Spectrometry of Faint Light
By John Meaburn, Astrophysics and Space Science Library, Volume 56, D. Reidel Publishing Company, 1976, pp. 270.

The measurement of the spectrum of the faint electromagnetic radiation reaching us from the Universe provides one of our richest sources of astronomical information. For example, the individual spectral lines which are present in a spectrum contain information about the chemical composition and the excitation and ionization states of the emitting region, while the line profiles themselves can be used to infer plasma temperatures and bulk velocities. These data then give the basic information necessary to understand the structure and dynamics of the Universe.

This book provides an extensive review of the many devices used to analyse the light collected by large telescopes, and of the systems used to detect this radiation. The scientific results obtained from the use of these instruments is not the subject of this book, although many examples of such results are displayed in order to illustrate instrument operation. The majority of the book thus deals in detail with the four main families of spectrometers in current use, namely those based on the many varieties of diffraction grating, the Fabry-Pérot interferometer, the two-beam interferometer (e.g. the Michelson) and finally the variety of crossed devices employing two or more of these elements in combination. There is also a short chapter on prism spectrometers which basically explains why these have been almost completely replaced by blazed reflection gratings, except in a few specialised applications (e.g. objective prism spectrographs).

The format of each section dealing with the four spectrometer families is similar, starting with the theory of the basic device in question (at a generally higher level than elementary), progressing onto the general arrangements and considerations necessary to make the idealised instruments work in practice, and finally to the designs of practical instruments for particular uses and the kind of results obtained with them. Emphasis throughout is placed on the practical aspects, such as for example, how to accurately measure the thickness of spacers for optically-contacted Fabry-Pérot etalons, or how best to make and store interference filters in order to minimise drift with time of the passband maximum.

Much attention is also given in the book to the intercomparison of competing spectrometers of various types.

In general, for any particular astronomical problem there will always be several spectrometers basically capable of doing the job, and the business of choosing the device which will give the best performance on the problem is often complex. The author has used various factors of merit, such as luminosity-resolution product, free spectral range, spectral and spatial simultaneity gain etc., which are tabulated for each instrument and then intercompared. However, the principal factor of merit of a spectrometer is the signal-to-noise ratio obtainable in a given observing time for each required spectral and spatial element. This is considered in the final chapter for problems involving the observation of an extensive source emitting either line or continuum radiation.

Finally, the book is on the whole reasonably well written, and is nicely produced. There are many large diagrams and photographs of high quality, although the figure captions do not always give adequate explanations. In addition, on quite a few painful occasions the text seemed to degenerate to the level of very rough notes, or worse. How some of this passed through the editorial process is difficult to imagine. One very good feature of the book, however, is the extensive references to the source literature which are given at the end of each chapter.

DR. S. W. H. COWLEY

Be and Shell Stars
Ed. A. Slettebak, D. Reidel Publishing Company, 1976, pp. 465.

The Symposium (held at Bass River, Massachusetts in 1975) and its related volume are dedicated to P. W. Merrill and D. B. McLaughlin, two pioneers in the field of B-emission and shell star observations.

The proceedings comprise some 48 papers in six basic divisions: (i) observations of Be stars; (ii) Be stars as rotating stars; (iii) new observational techniques; (iv) line formation in expanding atmospheres; (v) models and (vi) single *versus* binary stars. Whilst by necessity most papers are short, each section contains at least one review paper, of which there are ten in all. Quite a number of the contributed papers, in fact, appear in abstract form only, although many are followed by a verbatim report of the subsequent discussion arising.

In his introductory address, Plavec (President of IAU Commission 42 on Photometric Double Stars) outlines the problems in understanding Be and shell stars, *viz* (a) line formation in an extended atmosphere, (b) rapid rotation of the central star/Be character relationship and (c) origin and dynamical support of the extended atmosphere. The great similarity between certain Be stars, shell stars and close binaries is exemplified in the H-alpha profiles of 25 Ori (a classical Be star) and TT Hydrae (eclipsing binary); 88 Herculis (shell star) and RZ Scuti (eclipsing binary) amongst others. In a later paper (in Part vi) Plavec remarks on the hypothesis that a significant fraction of Be stars are interacting binaries and is of the opinion that observed Be stars are a mixture of three different types of object. As a Be star is merely a B star with an extended envelope, Plavec proposes three possible formation mechanisms: a rapidly rotating single star, a young star still surrounded by matter out of which it condensed, and an interacting binary system. However, the dilemma is that the single star hypothesis must explain quasi periodic V/R variations whilst the binary hypothesis must take account of the statistical expectancy of a relatively high number of eclipsing systems.

Harmanec and Kriz in a review paper, on the other hand, take the extreme view that *all* Be stars are interacting binaries. Whilst the hydrodynamics of the transfer of matter in such systems are very complex, qualitative models involving gas streams are discussed. The theme of models other than binaries is left to Part v, with a review paper by J. M. Marlborough.

Part iii, by far the longest section, contains no less than four review papers: radio observations (Purton), U.V. observations (Heap), photographic I.R. spectroscopy and near I.R. photometry (Swings) and polarisation (Coyne) of Be stars, whilst Part i review papers are on the spectra and photometry (Hutchings) and energy distribution (Schild) of Be stars. In a not inexhaustive appendix, Bidelman has compiled a list of "many of the hotter stars whose spectra have occasionally or continuously exhibited moderately conspicuous shell phenomena".

In his concluding remarks to the proceedings, Bidelman (in spite of the previous papers) inclines towards the view that the majority of Be stars are single rather than binary. Due to the diversity of objects termed B-emission, the whole study is perhaps best summed up by Bidelman in his quotation from Hamlet, "To *Be* or not to *Be:* that is the question"!

S. G. SYKES

OTHER PUBLICATIONS RECEIVED

The Story of Astronomy
By P. Moore, Macdonald & Jane's Publishers, 1977, pp.253, £6.95.

The 5th edition of the book, first published in 1961, testifies to its popularity. It is a large-format, well illustrated book with photographs and drawings on every page, including a number of pictures by David Hardy in colour.

Worlds Within Worlds
By M. Marten, J. Chesterman, J. May and J. Trux. Martin Secker & Warburg Ltd., 1977, pp. 208, £7.95 (hardback) £3.95 (paperback).

The spectrum of the Cosmos from the atomic and crystal worlds to those of microlife, human beings and the world around us, and then out into space are here presented in a basically large-format series of photographs with descriptive text. It is completely absorbing.

Ten Faces of the Universe
By F. Hoyle. Heinemann, 1977, pp. 207, £4.80.

The ten Universes, according to Hoyle, are those of God, the Physicist, Mathematician, Astronomer (who has three separate bites at the cherry), Nobody, the Geophysicist, Biologist and Everyman. Distinct views are brought together, interspersed with the author's own views and theories.

CORRESPONDENCE

New Social Order

Sir, In H. E. Ross's study on 'Extraterrestrial Communities' there are several challenging assumptions and statements. For instance,"... if the monetary system is wrong everything will be wrong."

I ask in all seriousness, is there such a thing as a 'right' monetary system? If there is, it has certainly never yet been devised. Our present almost world-wide monetary system (which is used by the so-called Communist world just as much as by the 'capitalist' countries) is so complex that no one understands it. In all my 57 years I cannot remember a time when there has not been some kind of financial crisis somewhere, often everywhere. What can one expect of a system which is an open invitation to selfishness, greed, exploitation and crime: which decrees that one must never do anything for anybody. only for money for oneself: which causes enormous unnecessary movement of goods across the world with consequent enormous waste of energy resources... I could go on.

You will say that, human nature being what it is, the monetary system is the only one that will work; that people must be made to work. If you do say that, I will say to you that your dream of devising a "scientifically-based new Social Order" on the Moon or anywhere else is but an empty and hopeless dream. There will be no Utopia unless man learns to know himself, to control his baser passions, to dedicate himself to the good of the community. If you don't believe this is possible, you can forget about your new Social Order. On the Moon, on satellites, anywhere, there will be the same greed, the same exploitation, the same hatreds, the same jealousies as here on Earth.

If, on the other hand, you do believe it is possible for man to change himself into a community of saints, you must see that this change is the inescapable prerequisite to a new Social Order – here or anywhere else.

One thing is certain. If man doesn't change, pretty quickly, he's for the high jump.

JOHN ALLISON
Tividale, Warley,
England.

Orbital Plane Calculations

Sir, The orbital plane of a satellite's orbit is defined by the Right Ascension of the orbit's ascending node (the point where the orbit crosses the equator on its northbound pass). However, this information is not given in the most easily available satellite listings. I have therefore devised an alternative approach for finding this type of information, which might be of use to other researchers who have had similar problems.

Initially, I calculate the ecliptic longitude which is due south at Greenwich at the time of the satellite's launch, and this can be found by simple arithmetic. The ecliptic longitude of the Sun at Oh (l_s) is given in the annual *Handbook* of the British Astronomical Association, among other publications: therefore, the longitude which is due south at Oh is approximately (l_s + 180) degrees. The Earth rotates through 360.9856° in 24 hours, so it is easy to see that at the time of the satellite launch, the due south longitude is:

$$l_o = 360.9856t + 180 + l_s$$

where l_o is the due south longitude and t is the launch time in decimals of a day UT. The value of l_o defines the plane of the satellite's orbit.

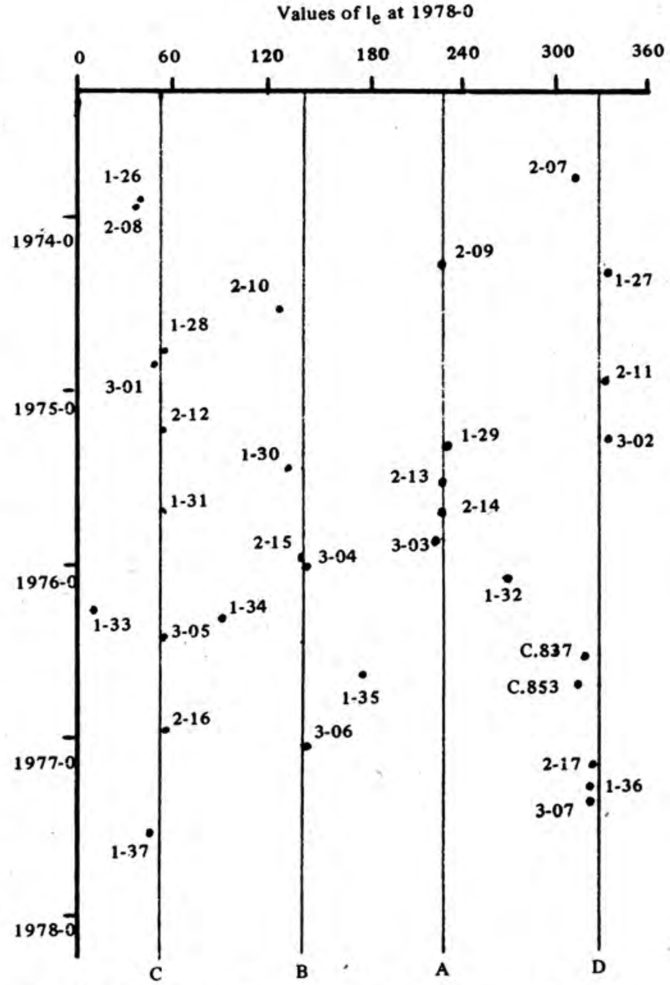

Fig. 1. Molniya Satellite Groupings. This shows the projected values of l_e for the Molniya launches to 1 - 37 at 63°. Cosmos 837 and Cosmos 853 are failed Molniya 2 satellites, given the Cosmos name. The groups A, B, C and D follow those of G. E. Perry.

In the course of time, the orbit precesses about the celestial sphere, by an amount given by:

$$\frac{dN}{dT} = \frac{-1440 \times 540 \times .00108}{P} \times \left(\frac{6378}{a(1-e^2)}\right)^2 \times \cos(i) \text{ deg/day}$$

where we have:

- P orbital period of satellite in minutes
- a semi-major axis of satellite's orbit, ½(apogee + perigee) + 6378
- e eccentricity of satellite's orbit, (apogee – perigee)/(2 x a)
- i inclination of the satellite's orbit

The satellite's orbital plane is projected forward to some specific date (epoch), where it can be compared with the planes of other similar satellite orbits. If we represent (epoch – launch date) by T, the longitude of the orbital plane at the epoch (l_e) is:

$$l_e = l_o + T\left(\frac{dN}{dT}\right)$$

I have applied this method to the Molniya 1, 2 and 3 system of Soviet communications satellites. These are launched from both the Tyuratam and Plesetsk cosmodromes, so I have added 74.5° to the longitudes of the Tyuratam satellites, so that the difference in launch sites is allowed for (this figure can be obtained by spherical trigonometry for orbits at 63° – the corresponding value for the 65° launches is 57.9°). Previously it has been shown by Mr. G. E. Perry that the present Molniya system mainly consists of four groups of satellites with their orbital planes being 90° apart (there are some launches in the Molniya-1 group which do not fit the main groupings, and these might be for military communications satellites): his most recent listing is presented in his *Royal Air Force Quarterly* article "The Molniya Communications Satellites" (Vol. 17, No. 2, pp. 154-162).

Figure 1 shows the orbits of the 63° Molniya satellites up to Molniya 1-37, and the results are in good agreement with those of Mr. Perry.

PHILLIP S. CLARK
Bradford, West Yorks, England.

Mystery of Cosmos 929

Sir, We have been watching with some interest the mission of Cosmos 929, launched on 17 July and (as of mid-October) still hooting away with manned-type telemetry formats. Analysis by Richard Flagg suggests that the spacecraft is a dual vehicle with very similar but not identical telemetry readings. Sven Grahn noted that after a major manoeuvre in August, a 166 MHz signal ceased permanently, and there has been other reason to suspect that at that time a portion of the satellite was detached and deorbited (although *not* necessarily recovered).

Lumping mysteries together, and seeking patterns where they may or may not exist, there seems to be some connection with Cosmos-881/882, launched about 15 December/0100 GMT, on a mission which was "successfully completed" during the first orbit! The *TRW Space Log* says that the booster was a Proton. Visual observations of Cosmos 929 also indicate that it is big, 'Salyut-sized,' and hence also launched by a Proton.

As best I can reconstruct the manoeuvres, from NORAD tracking data, here is the history of Cosmos 929:

17 July	Launch 0900 UT, 89.40, 227-275 (period in minutes, perigee-apogee, km).
27 July	Manoeuvre, rev 160, from 89.13 to 89.19 (apogee raised 3 km).
30 July	Manoeuvre, rev 208, from 89.10 to 89.17 (apogee raised 3.5 km).
2 Aug	Manoeuvre, rev 256, from 89.06 to 89.19 (apogee raised 7.5 km).

Here telemetry changed

17 Aug	Manoeuvre, rev 509, from 88.55 (193 x 224) to 88.94 (222 x 235).
18 Aug	Two manoeuvres on/about rev 525, raised to 90.77 (306-330).
22 Aug	Manoeuvre, rev 588, 90.75 (314 x 321) to 90.78 (315 x 323).
26 Aug	Manoeuvre, rev 650, 90.77 (315 x 322) to 90.86 (317 x 329).
31 Aug	Manoeuvre, rev 729, 90.85 (317 x 329) to 90.89 (317 x 332).

No further manoeuvres through 15 October, just a slow decay.

What is it? My own guesses concentrate on the 'kosmobuksir,' or 'space crane,' a tug-boat to push together separately launched pieces of the assembled space station. From past Soviet methodical testing, the assembly of a large space station could be planned for the second half of 1978.

JAMES OBERG
Houston, Texas,
USA.

Three years ago cosmonaut Vladimir Shatalov, who heads the Soviet cosmonaut group, revealed that Soyuz was being developed as a "universal spacecraft" – for carrying crews, fuel and provisions to scientific stations and for the assembly of complex space structures in orbit. Ships of this type, he said, "undoubtedly will become assembly sites for large space stations to be set up in orbit." Ed.

Coat of Arms

Sir, There seems to be a continuing interest in the Society's symbolism, particularly the adoption of a motto. An organisation's motto is normally part of its heraldic insignia and certainly if the Society used a motto with its current logo it would be considered heraldic. Unfortunately use of coats of arms which have not been correctly granted is illegal (in England the machinery for prosecution is rusty, but in Scotland the Society could find itself in Court).

With regard to the comments on mottos that have been made by various correspondents, a motto can be in any language and need not be unique, so "Ad Astra" could still be used if wanted. Latin is the most common and traditional language because when heraldry developed it was the international and scholarly means of communication; it is still useful because of its extremely concise nature often using half the words of its full English translation.

I think in view of the interest shown and the irregular nature of the current state of affairs, the Council should consider obtaining a grant of arms. The existing logos could be incorporated in its present form and the motto could be chosen by a competition as suggested by H. E. Ross. Although it would be too expensive for the Society to undertake while moving offices, it would make an excellent 50th birthday present as well as putting a symbolic touch to the results of the Society's Development Programme.

C. M. HEMPSELL
Hatfield, Herts,
England.

Origin of Planets

Sir, I read with much interest the article 'Planet-Forming Star' (*Spaceflight*, October 1977). The suggestion that a disc shaped stellar object MWC349 discovered in the constellation of Cygnus may be a relatively young star surrounded by a disc of intensely glowing gaseous material, within which planets may be forming, is particularly attractive when applied to the known facts about our own Solar System.

Firstly, the idea of the major planets forming from a disc of material orbiting the Sun would account for the fact that the major planets orbit approximately on or near the plane of the ecliptic. Secondly, planets formed in this way would presumably follow near circular orbits as do our major planets. Thirdly, an interesting fact to note is the rather odd discovery brought to notice by an astronomer Johann Elert Bode in 1772 concerning planetary distances. Bode stated that if we take the number 0, 3, 6, 12, 24, 48, 96 and 192, each being double its predecessor (except 0 of course), and then add 4 to each giving 4, 7, 10, 16, 28, 52, 100 and 196. Taking the Earth's distance from the Sun as 10 units the remaining figures give the distances of the other planets from the Sun fairly accurately:-

Planet	Distance from Sun according to Bode	Actual distance
Mercury	4	3.9
Venus	7	7.2
Earth	10	10
Mars	16	15.2
- - -	28	- - -
Jupiter	52	52
Saturn	100	95.4
Uranus	196	191.8

It is of interest to note that Bodes Law was proposed prior to the discovery of Uranus, which like the other planets fits well into the table. A coincidence? Could it be that when our Solar System came into being the planets formed with these relationships of distance as a result of the way in which the loose material in the disc of matter orbiting the Sun behaved under the influence of gravitational and other possible forces? Could it also be that when loose material collects to form a planet sized body it may curve or spiral in towards the centre of that body thus causing the spinning motion which most planets exhibit?

I feel that these questions deserve serious study for if it is proven that this kind of activity takes place during the formation of stars it would have the effect of greatly increasing our estimates of the number of stars having planetary families and thus enhance our expectations of discovering life-bearing planets.

R. MILNE
Hornchurch, Essex,
England.

On the VfR and 'Die Rakete'

Sir, Last year Frank H. Winter published in these pages an outstanding history of the German Verein für Raumschiffahrt e.V. [1]. Subsequently, in the letter column, he noted the confusion surrounding the date of the VfR's formation and also just when the journal *Die Rakete* came into being [2].

He correctly stated that the Society was founded on the 5th of July 1927 and not on the 5th of June as often recorded in the rocket literature. Wernher von Braun and I are guilty of using June in the three editions of our *History of Rocketry and Space Travel* (1966, 1969, 1975), having taken the date from Willy Ley's 1932 chronology *Grundiss einer Geschichte der Rakete.* Surprisingly, Ley continued the error in his rocket-space histories (*Rockets*, 1944; *Rockets and Space Travel,* 1947; *Rockets, Missiles and Space Travel,* 1951, and *Rockets, missiles, and Men in Space,* 1968).

Aside from the *Grundriss,* what did other prewar books have to say about the VfR's formation? For his part, Otto Willi Gail (*Mit Raketenkraft ins Weltenall,* 1928) referred only to the summer of 1927; no specific date. A year later, A. B. Scherschevsky in *Die Rakete für Fahrt und Flug* got it right: 5 July 1927. However, Rudolf Nebel's 1932 *Raketenflug* would play it safe by saying that "By the year 1927, Valier and Winkler had formed the Verein für Raumschiffahrt." Max Valier himself could not, of course, mention the Society in 1924 when *Vorstoss in den Weltenraum* first appeared, but by the time that popular work had been expanded into *Raketenfahrt* in 1928 he was recording 7, not 5, July! And in I. Esser's (1968) biography *Max Valier: Ein Vorkamfer der Weltraumfahrt 1895-1930* both the 5 June


DEUTSCHE JUGEND-ZEITUNG
Anregungen für die heranreifende männliche Jugend

INHALT:
Der Flug zum Monde, seine astronomischen und technischen Grundlagen. — Vom Erfinden. — Für Bastler: Selbstanfertigung einer Vorrichtung zur Verbesserung des Detektorempfangs. — Bücherbesprechungen. — Rätsel-Ecke.

Nr. 1 Januar 1927

and 5 July dates appear in separate p .ces, without comment.

Postwar German rocket historians offer us the same choices. In *Start in die Dritte Dimension*, Alfred Fritz writes ' On 5 June 1927, in the parlour of an alehouse in Breslau, the Verein für Raumschiffahrt was founded. Johannes Winkler took the chair after Valier had refused to do so because of his many tour obligations." In the same vein, Heinz Gartmann (*Träumer, Forscher, Konstrukteure*) tells us that ' The 5th of June 1927 was an important date in the history of rocketry, for on that date in Breslau a group of about a dozen men, most of them young, founded the Verein für Raumschiffahrt. Even Rudolf Nebel fell into the June trap in his fairly recent (1972) *Die Nerren von Tegel.* Hans K. Kaiser, however, recorded the correct date in *Kleine Raketenkunde* published in Stuttgart in 1949.

All of this suggests that one should go to the source whenever possible. In the case of the VfR, a logical source is their journal, *Die Rakete*. As Frank Winter pointed out, on page 82 of the ' first" issue, dated 15 July 1927, we read that the Society was created on the 5th of the same month at 6½ hours in the afternoon at the Golden Zepter, Schmiedebrücke 22, Breslau.

So much for the Society itself.

Now, what about *Die Rakete*? I put quotes around "first" for good reason, for what I meant was the first issue of *Die Rakete* published by the newly founded VfR. But in fact, it was not really the first issue.

Then what was? For many years I was puzzled as to why the alleged 15 July 1927 first issue of the journal should start off with page 81. Where were the first 80 pages? I could not believe that between the 5th of July, the date of VfR's formation, and the appearance ten days later of *Die Rakete* that some other journal material had been published

by the fledgling Society.

Back in 1965, Harry Ruppe (then of Huntsville, Alabama and now of Munich) and I loaned our copies of *Die Rakete* to the Johnson Reprint Corporation of New York so that a reprint volume could be prepared. In the foreword to the resulting book containing the collected *Die Rakete* reprints, we noted that

> The 1927 volume of *Die Rakete* is continuous from July through December. These issues are preceded by one dated January-June which purports to be a collection of the significant papers appearing in the journal prior to the formal establishment of the Society. It contains 28 pages whereas the original (even then) out-of-print issues apparently contained 80 pages, explaining the break in pagination in the 1927 volume. The numbers released during the first six months of 1927 were probably informal in character.

I now know better. In an attempt to get at the bottom of the *Die Rakete* mystery, in October 1966 I visited the Deutsches Museum archives in Munich. With the kind help of Ing. Ernst Klee, we went through the early rocket documentation and found that in January 1927 – a full six months before the VfR came into being – Johannes Winkler had launched the *Deutsche Jugend-Zeitung.* The lead article of the 32-page magazine, whose cover is illustrated, was entitled ' Der Flug zum Monde."

Almost identical in format was issue No. 2; the difference was accounted for by the title, which Winkler had changed to *Die Rakete.* Directly underneath the title he had added *Zeitscrift für Raumschiffahrt vereinigt mit "Deutsche Jugend-Zeitung" in Breslau.* Since it was dated 15 April 1927, a pre-VfR *Die Rakete* did, indeed, exist (incidentally, its first page was 33). All the while, Winkler considered the magazine to be the second issue of *Deutsche Jugend-Zeitung.* Confusing?

Shortly later, the VfR was established and its membership wanted to acquire copies of Winkler's *Deutsche Jugend-Zeitung/Die Rakete* magazines that had appeared during the preceding six months. Since supplies quickly became exhausted, the January-June supplement ("Ergänzungsheft") was published to satisfy membership demand to fill out the 1927 year. The supplement's lead article was, appropriately, *Deutsche Jugend-Zeitung's* original lead ' Der Flug zum Monde." And so 80 pages of material one to six months old were compressed into 24 pages, with no explanation for posterity as to what had happened.

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1. Winter, Frank H., "Birth of the VfR: The Start of Modern Astronautics," *Spaceflight,* 19 Nos. 7 & 8 , pp. 243-256, 1977.
2. "The VfR and 'Die Rakete,' " *Spaceflight,* 19, 9, p. 336, 1977. Ironically, an error crept into Mr. Winter's letter. In paragraph four we read "Even the date of 15 July 1927..." (It should, of course, be 5 July 1927!).

FREDERICK I. ORDWAY
Washington, D.C., USA.

Insight of a Former BIS Chairman

Sir, As part of the general membership of the British Interplanetary Society, may I pay tribute to Mr. Arthur C. Clarke for giving so much to the Society. I refer not only to his generous donation of £10,000 (which has stimulated this letter), but also to the fine contribution to Space Technology he has made.

It was Arthur Clarke, for example, who first conceived the idea of communications satellites, but it is as a science-fiction writer that he is best known to the world at large.

Most science-fiction writers are overtaken by advances in knowledge and technology that, after a few years, make their novels seem ridiculous, but I think Clarke is unique in having caused the advances that date his work himself.

In his film *2001 – A Space Odyssey* he describes how Bowman is stranded outside his ship because of a malfunction in the ship's computer. The only way to get back is to try something illogical, and thus beyond the comprehension of the computer. He jumps through the vacuum of space without a spacesuit.

By his writing Arthur C. Clarke has posed the question, "Is it possible for humans to be briefly exposed to the vacuum of space?" Dr. Michael Bodin says "Yes" [1]. In a sort of literary howl-round, Clarke has invalidated his own book since, by the year 2001, HAL, the ship's computer, will no longer think that Bowman's action is illogical, and will have thwarted his attempt to regain the ship!

I would like to draw attention to an even earlier work of Clarke's, *The Sands of Mars* which was first published in 1951 [2], in chapter 9 of which he describes a journey up a Martian valley. Such valleys were not foreseen until Mariner 9 so dramatically revealed them in 1971.

The valley in *Sands of Mars* flowed into *Mare Erythraeum,* and Clarke's heroes turned up a tributary to that valley and found a crater (actually Clarke refers to it as an amphitheatre) two kilometres in diameter. Again, it surprised the World in 1965 when Mariner 4 showed Mars to be crater scarred.

By reference to an atlas of Mars [3], such a valley can be found running into *Mare Erythraeum,* and it is consistent with the areography of the book. Moreover, at the head of a tributary is a crater, which is, as near as I can estimate, two kilometres in diameter and situated at 27°S, 43°W.

May I request any of our members that might have any influence over naming Martian features to call the valley "Clarke's Valley" and the crater "Gibson" after the hero of the book, in recognition of Arthur C. Clarke, a former BIS Chairman, who by his insight has contributed a good deal to Man's quest for space flight.

GEOFFREY HUGH LINDOP
Kirkbride, Carlisle, England.

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2. Clarke, A. C., *Sands of Mars,* Sidgwick and Jackson Limited, (1951); also Pan Books Limited, London (1964).
3. Moore, P. and Cross, C. A., *Mars,* Mitchell Beazley Limited, p. 37, (1973).

Spaceflight

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: Tel: 01-821 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor 12, Bessborough Gardens, London, SW1V 2JJ.

Opinions in signed articles are those of contributors, and do not necessarily reflect the view of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Lecture
Title **JUPITER** by Dr. G. E. Hunt.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **1 February 1978**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Western Branch
Theme **ENVIRONMENTAL FILM SHOW**
The programme will include the following films:

(a) Question of Life

(b) The Pollution Solution

(c) The Fractured Look

(d) Universe

To be held in the Main Engineering Lecture Theatre, Queen's Building, University Walk, Bristol, on **10 February 1978**, at 7.15 p.m.

Admission tickets are not required. N.B. No university car parking facilities are available but there are Public Car Parks at Park Row, Berkeley Place, and limited parking in roads around the University Precinct.

Lecture
Title **THE OUTER PLANETS** by Dr. G. E. Hunt.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **2 March 1978**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Lecture
Title **MINOR BODIES IN THE SOLAR SYSTEM** by Dr. D. W. Hughes.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **15 March 1978**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

15th European Space Symposium
Theme **APPLICATIONS SATELLITES**
To be held in Bremen, Germany, on **8-9 June 1978.** Co-sponsored jointly by the DGLR, AAAS, AIDAA and BIS.

Subject areas will emphasise the following aspects:

(1) Telecommunications Satellites.

(2) Meteorological/Remote Sensing Satellites, User and Ground Facilities.

Offers of papers are invited. Further information is available from the Executive Secretary.

29th I.A.F. Congress
The 29th Congress of the International Astronautical Federation will be held in Dubrovnik, Yugoslavia, from **1-8 October 1978.**

Further details will be announced later.

CHANGES OF ADDRESS

Notification of new addresses must arrive at the Society's Offices by the 5th of the month if they are to be incorporated in the dispatch list for that month. Requests received afterwards can only be incorporated in the *following* month.

BIS DEVELOPMENT PROGRAMME

WILL YOU HELP US REACH OUR £25,000 TARGET?

A MAJOR RE-DEVELOPMENT of the Bessborough Gardens area of London in which the Society's headquarters are located compels us to obtain new premises. We have therefore launched an urgent Appeal to raise £25,000 as a downpayment on alternative office accommodation.

The Appeal is linked with our long-term aims to develop the Society in several important directions:

- **TO EXTEND EDUCATION IN SPACE RESEARCH AND TECHNOLOGY TO EMBRACE A WIDER COMMUNITY;**
- **TO EMPHASISE THE RAPIDLY INCREASING SOCIAL AND ECONOMIC BENEFITS OF SPACE APPLICATIONS;**
- **TO EXPAND FORWARD-LOOKING STUDIES IN ASTRONAUTICS ON AN INTERNATIONAL BASIS;**
- **TO INCREASE OUR MEMBERSHIP AT HOME AND ABROAD.**

EXECUTIVE SECRETARY
BRITISH INTERPLANETARY SOCIETY
12 Bessborough Gardens, London SW1V 2JJ.

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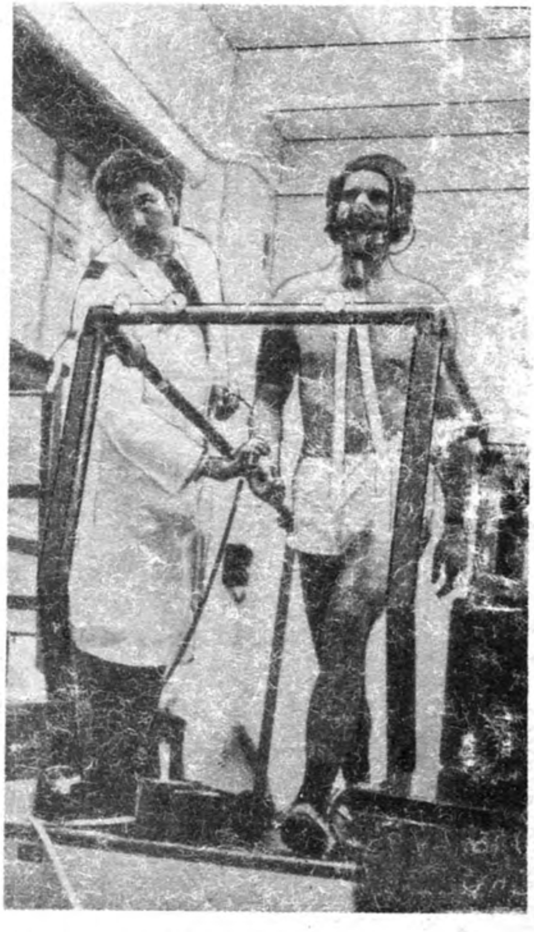

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CONTENTS

COVER

SPACELAB CANDIDATES. Of the large number of talented people who applied to undergo training for the first Spacelab mission in 1980, the field has been narrowed to just four Europeans and six Americans (see page 82). From this number will be selected one European and one American to fly on the actual mission. Others will serve as specialists on the ground. Three of the 10 finalists: *top left,* Dr. Franco E. Malerba, 31, Italian engineer working in the computer field for the Digital Equipment Corporation in Milan; *right,* Dr. Ulf Merbold, 36, German research scientist working in the field of crystal lattice defects at the Max-Planck-Institut für Metallforschung in Stuttgart; *below,* Mrs. Ann F. Whitaker, 38, physicist working at the Marshall Space Flight Center, Huntsville, Alabama.

European Space Agency/National Aeronautics and Space Administration

MILESTONES

December

1 First US Navy Fleet Satellite Communication (FLTSATCOM) satellite, built by TRW Defense and Space Systems group in Redondo Beach, is shipped to Cape Canaveral. Satellite will provide worldwide, high-priority UHF communications between naval aircraft, ships, submarines and ground stations, Strategic Air Command and the presidential command networks. The 4,100 lb. (1,860 kg), three-axis stabilised satellite, will be launched by an Atlas-Centaur into geo-stationary orbit. An 18-turn helical UHF receive antenna and a 16 ft. (4.87 m) deployable parabolic UHF transmit antenna will provide point to point communications for small mobile users. Solar arrays will provide 1,200 W of power.

7 ESA Meteosat reaches its on-station position in geostationary orbit (at 0° longitude) above Gulf of Guinea.

9 Meteosat takes its first pictures of the Earth's surface and cloud cover in the visible and infrared regions of the spectrum.

10 Soviet Union launches Soyuz 26 from Tyuratam at 4.19 a.m. (Moscow time) with cosmonauts Lt-Col Yuri Romanenko, 33, and flight engineer Georgi Grechko, 46. After five orbits completed at 12 hours Moscow time, orbit is adjusted to 267 x 329 x 51.6 deg; period 90.2 min.

11 Soyuz 26 docks with Salyut 6 space station at 6 hr. 02 min. (Moscow time) using second docking port which is located on instrument section at opposite end to that used, unsuccessfully, by Soyuz 25 cosmonauts. Cosmonauts enter station some three hours later after equalising atmospheres and opening transfer hatch. Mission programme includes "study of physical processes and phenomena in outer space; exploration of Earth's surface and atmosphere for obtaining data of interest to national economy; bio-medical investigations, technical experiments and testing of onboard systems and instruments; also checking and testing of docking assembly on transfer compartment (which failed to operate correctly on previous mission)."

13 British Skylark rocket, TEXUS 1, is launched from Kiruna range in Sweden in first of series of German DFVLR experiments to study potential of manufacturing new light weight/high strength alloys and glasses, ceramics and crystals, etc., in space. TEXUS 1 (Technological Experiments under Zero Gravity with Sounding Rockets) carried eight experiments for various West German organisations and one experiment for the Swedish Royal Institution of Technology. They were mainly concerned with the crystallisation and segregation of metals, the diffusion processes of glass samples, the behaviour of liquids and the effects of zero gravity on electrolysis. Payloads flown in Skylark can be subjected to up to eight minutes of micro-gravity conditions. Experiments will assist in selection of those to be flown in ESA Spacelab in the 1980's.

13 First test firing of complete first stage of ESA Ariane launch vehicle is carried out at Société Européene de Propulsion (SEP) at their Vernon test centre. The stage, which operated for 111 seconds, was in flight configuration and consisted of the propulsion bay (four Viking II engines), the flight-standard tanks, the forward skirt and the intertank skirt.

13 Salyut 6 completes 1,188 Earth orbits by 2 p.m. (Moscow time), 34 with a crew onboard. Orbit ranges between 337 x 363 km inclined at 51.6 deg to equator; period 91. 4 min. Although work to activate the

[Continued overleaf

equipment has not been completed, doctors at mission control decide to give the crew "a day of active rest." Dr. Konstantin Feoktistov, the cosmonaut who is also one of the team leaders responsible for the design of Salyut stations, says provision of two docking ports in Salyut 6 "gives a bigger safety margin, especially in docking operations, and opens up the possibility of simultaneous work of the station with two transport ships. Additional deliveries of scientific equipment and food can be made."

19 Salyut 6 completes 1,283 Earth revolutions by 14.00 hr. (Moscow time) of which 129 were with a crew on-board. Orbit ranges between 335 and 365 km inclined at 51.6 deg to the equator; period 91.4 min.

20 Cosmonaut Georgi Grechko performs EVA from Salyut 6 to inspect and photograph (with colour TV camera) possible damage resulting from Soyuz 25's abortive docking attempt in October and to carry out any necessary repairs. Spacewalk – begun at 00.36 hr. (Moscow time) – ends after 20 minutes without revealing any damage. Total operation including de-pressurisation and repressurisation of transfer com-partment lasted 88 min. During EVA Yuri Romanenko remained in the depressurised transfer compartment and controlled the space walk. Both men wore "a new type of semi-rigid, full pressure spacesuit."

20 Large solid-propellant rocket motor of USAF's Interim Upper Stage (IUS) completes 150-second test firing at Air Force's Arnold Engineering Development Center in Tullahoma, Tennessee. The United Technol-ogies' Chemical System Division motor is designed for an exceptionally long firing time to provide the IUS with extended but low accelerations of a type that IUS-boosted payloads easily can endure. Its average thrust is 47,000 lb. (21,319 kg). Propellant is composed of 86 per cent solid fuels with 18 per cent aluminium. The motor tested contained 20,000 lb. (9,072 kg) of the propellant. The IUS system also will employ a second rocket motor providing 27,000 lb. (12,247 kg) of thrust. Through various arrangements of one, two or three of these motors, Interim Upper Stages can meet almost all Shuttle-related mission requirements. The IUS is also to be used as an upper stage for the USAF's new Titan III space booster.

21 NASA's National Space Technology Laboratories at Bay St. Louis completes first tanking test of the Space Shuttle's External Tank (ET). Test is considered a major milestone leading to first tests of the Shuttle's LO_2/LH_2 main propulsion system in the Spring of 1978. *[In the tanking test, after the ET was filled, the propellants were allowed to flow through the connecting piping to the three engines until they were stopped by the main engine valve. Several days earlier, the ET had been filled with a 40 per cent load of liquid oxygen and vibrated with three large shakers to provide information on the natural frequencies of the main propulsion test article].*

22 European Space Agency announces selection of four candidates as Spacelab payload specialists: Franco Malerba, 31, Italian engineer working in the computer field for the Digital Equipment Corporation in Milan; Ulf Merbold, 36, German research scientist working at the Max-Planck-Institut für Metallforschung in Stuttgart; Claude Nicollier, 33, Swiss researcher and pilot who has since 1976 been a visting scientist at ESTEC, Noordwijk, Netherlands; Wubbo Ockels, 31, Dutch physicist doing research work and lecturing at Groningen University. *[Among the last 12 in the run-ning were candidates from Belgium, Denmark, France, Britian and Ireland in addition to the countries of the four finally selected].* By May 1978, three of their number will be selcted for appointment to the staff of ESA to undergo training for the first Spacelab flight. A few months before the mission, one candidate will be chosen to become the first West European to travel and work in space. The two others will serve as back-up specialists for the first flight currently scheduled for December 1980 and will participate in ground-based mission activities. At the same time NASA announced the names of the six US scientists who are finalists for the first flight of Spacelab: Criag L. Fischer, MD, 40, The Palm Desert Medical Group, Inc., Palm Desert, California; Michael L. Lampton, Ph.D., 36, University of California, Berkeley; Byron K. Lichtenberg, Ph.D. candidate, 29, Massachusetts Institute of Technology; Robert T. Menzies, Ph.D., 34, Jet Propulsion Labora-tory, Pasadena; Ann F. Whitaker, M.S., 38, Marshall Space Flight Center, Huntsville, Alabama (materials specialist who is a co-investigator on one Spacelab 1 experiment); and Richard J. Terrile, Ph.D., 26, California Institute of Technology, Pasadena. Two final candidates will be chosen from this group. Of the 10, two (one American and one European) will even-tually be selected to fly aboard Spacelab and operate its science equipment.

29 Flight trajectory of Salyut 6 is modified by engine burn of attached Soyuz 26 ferry. Orbit now 334 x 371 km x 51.6 deg; period 91.3 min.

30 Salyut 6 completes 1,454 revolutions of Earth, 300 with a crew on board, by 12.00 hr. (Moscow time).

January

7 Mission control centre reports that Salyut 6/Soyuz 26 have made 450 manned orbits of the Earth. Station has been relying completely on an automatic orienta-tion and control system. Alexei Yeliseyev, flight director, describes the Delta automatic navigation system as one of the most important engineering achievements of the mission; it has relieved the cos-monauts of many routine tasks. Soviet biologists have an experiment aboard called 'Medusa' which is concerned with "the problem of the origin of life in the Universe." Its purpose is to determine what

[Continued on page 104

MARTIAN DUST STORMS - A MECHANISM FOR TRANSPORTATION OF LIFE?

By Geraint Day*

Great dust storms on Mars have been observed from Earth for many years. Spacecraft visits to the Red Planet have given information on the composition of its surface and the prevailing conditions. In particular, fine silicate particles have been observed by the Viking lander spacecraft. Given the right biological conditions certain organisms could participate in the global transport of dust – either at the present time or in Mars' past.

Introduction

Photographs sent to Earth from the NASA Viking 1 and 2 Landers have revealed distinct "sand" dunes. Dunes were first seen, on a larger scale, by the Mariner 9 spacecraft as it orbited the planet. It is known that some of the particles in these dunes – which may cover quite a large proportion of the surface of Mars – get carried into the Martian atmosphere to form yellow clouds and the great dust storms. If, somewhere on Mars, the surface covering of sand and dust were to contain living organisms there would be important consequences for the distribution of these organisms over the surface of the planet, due to their continual movement by wind.

The Dust Storms

When Mariner 9 arrived in Martian orbit on 14 November 1971 all that its two TV cameras could show of Mars was a largely featureless globe. The high resolution camera was designed to be able to pick out features as small as 100 m across and yet hardly any surface contrast was discernable. (Occasionally some dark patches, along with the planet's south polar cap, revealed themselves on the television frames). The reason was that Mars was shrouded in a thick pall of dust – a planetwide dust storm.

At each opposition since 1877 yellow obscuring clouds have been observed by astronomers as they studied the disk of Mars [1, 2]. The fact that these clouds "had the colour of Mars," (an earlier report by the amateur astronomer H. Flaugergues gave this description) and their origin appearing to be in the bright so-called desert areas of the planet, led to the notion that they were composed of surface-covering particles blown about by winds. A major outbreak of clouds is analogous to a terrestrial dust storm, only on a larger scale.

The observational record shows that yellow clouds are more abundant when Martian perihelion and opposition coincide. Thus, in 1892, 1909, 1924, 1956 and 1971 there were reports of total obscuration of the Martian surface. Perihelic opposition occurs once every 15 years or so. At such times the disk of the planet can appear nearly 26″ in diameter – a figure about twice the maximum for an opposition when Mars is furthest from the Sun, and seven

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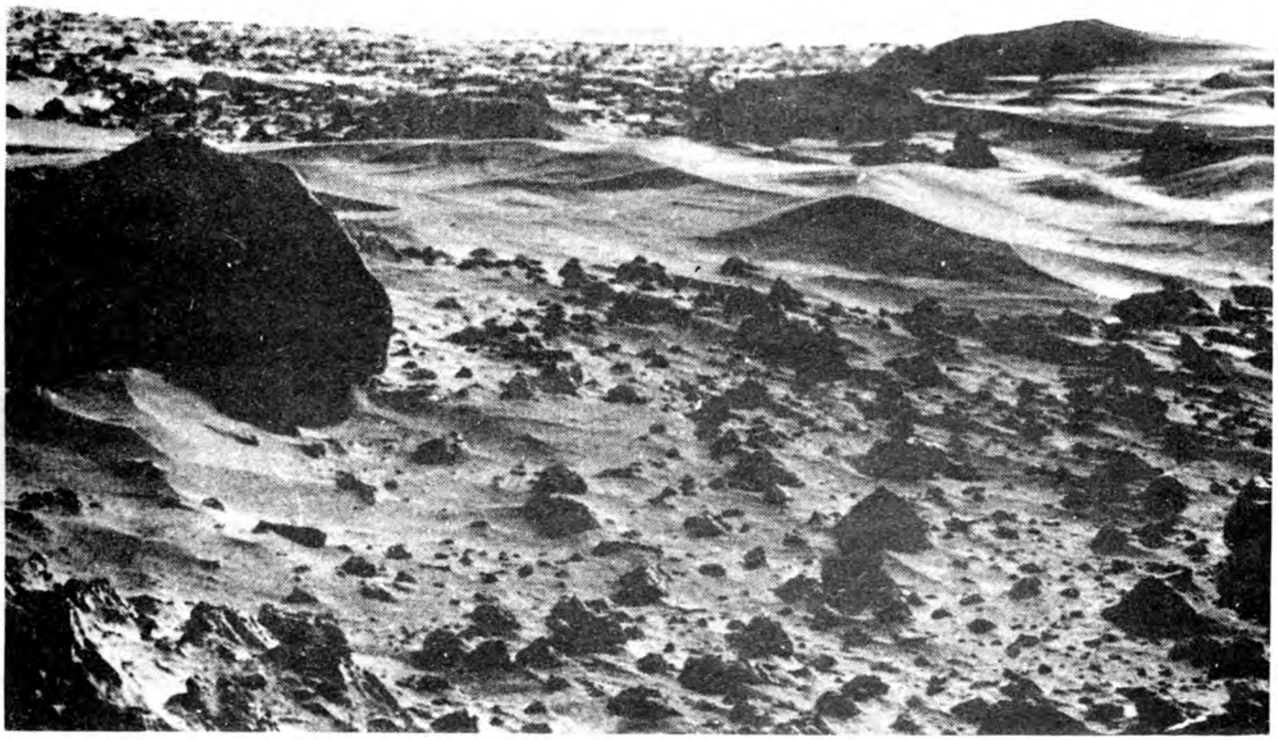

A Viking 1 Lander television view of a dune field on Mars, taken on the early morning of 3 August 1976. The particles comprising the dunes are thought to be mostly $<100\ \mu m$ in effective diameter (approximating them to spheres). They are small compared with typical desert sand grain sizes on Earth of $\sim$2mm. The sharp dune crests give an indication of the last winds able to move particles over the dunes. Clay particles and limonite (a mixture of hydrated iron oxides and hydroxides) are likely constituents of the Martian regolith. The large boulder on the left of the picture is about 8 m from the spacecraft and it measures approximately 1 m x 3 m. The scene is in *Chryse Planitia.*

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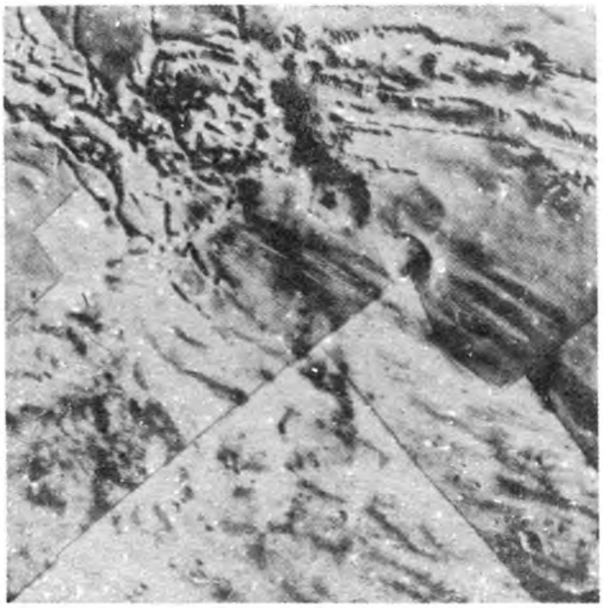

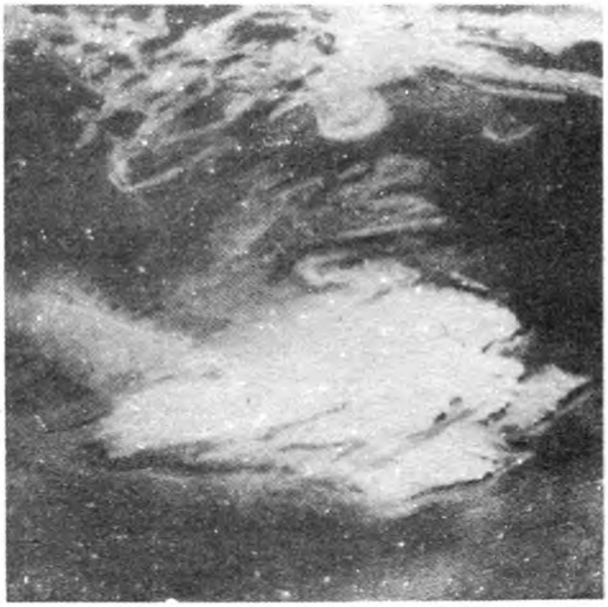

DUST STORMS ON MARS 'BEFORE AND AFTER.' Picture at right shows a dust storm about the size of the state of Colorado covering a portion of Mars known as *Valles Marineris*. The structure and appearance of the cloud mark it as a dust storm; the leading edge is sharp, while the trailing edge is diffuse. Cellular structure in the cloud indicates strong turbulence and upward motion. Picture was taken by Viking Orbiter 2 on 25 March 1977. The 'before' picture, left, is a mosaic of several frames taken by Viking Orbiter 1 on 31 July 1976. It shows the same area partly covered by clouds, probably partly due to cooling air as it is carried upward by strong winds, forming water-ice clouds.

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times the smallest apparent diameter [3]. There is a selection effect in that any details on Mars are best seen at times when the disk has a large apparent size; in other words, at times of perihelic opposition. In fact, dust storms were seen in 1928 and 1973, for instance, when Mars was not at its closest to Earth [4]. But there is apparently a link between perihelion and the onset of the storms.

Yellow clouds – which are usually opaque, mobile and persistent – tend to occur mostly in the southern hemisphere from longitudes 270° to 70° (i.e. from *Hellas Planitia* to *Argyre Planitia*). At perihelion it is Summer in the southern hemisphere of Mars and the insolation is greater than normal by ~ 20%. Maximum heating of the ground by the solar rays occurs along a belt centred at latitude 20°S. In suitable regions and under suitable conditions it is possible to generate "dust devils." These can occur when there is atmospheric instability. When there is a large overheating of the ground weak and moderate winds are able to whip up any loose overlying material by friction. The efficiency of dust devil activity is, in general, not known – it depends on the quantity of dust and small particles present. Where the particle trajectories intersect the ground they are able to knock other particles up into the air – the process known as saltation. Turbulent mixing can propagate already-suspended dust to greater heights. Once a cloud of dust and small particles reaches a large enough size and number density it is able to considerably alter the temperature balance of the enclosing atmosphere. So high speed winds appear, which in turn raise further quantities of dust.

On Mars the process is so effective that it took less than 20 Martian days (a day on Mars is only 41 minutes longer than ours) for an initial localised disturbance to result in a completely shrouded surface at the start of the great 1971 dust storm [5].

Because Mars has a very wide range of *relative* pressures, even over fairly short distances, in its tenuous, mainly CO_2 atmosphere (mean surface pressure around 6 mb), it is able to respond rapidly to any changes in temperatures and pressures. The range of relative pressures on the surface – influenced by topography – is quite large. For instance, at the top of the giant volcano *Olympus Mons* (elevated 23 km above the mean planetary surface level) it is about 2 mb, but at the base of a depression such as *Hellas Planitia* the value approaches 9 mb [6]. A dust cloud moving upwards inside such a basin can eventually spill out into the rather less dense atmosphere outside.

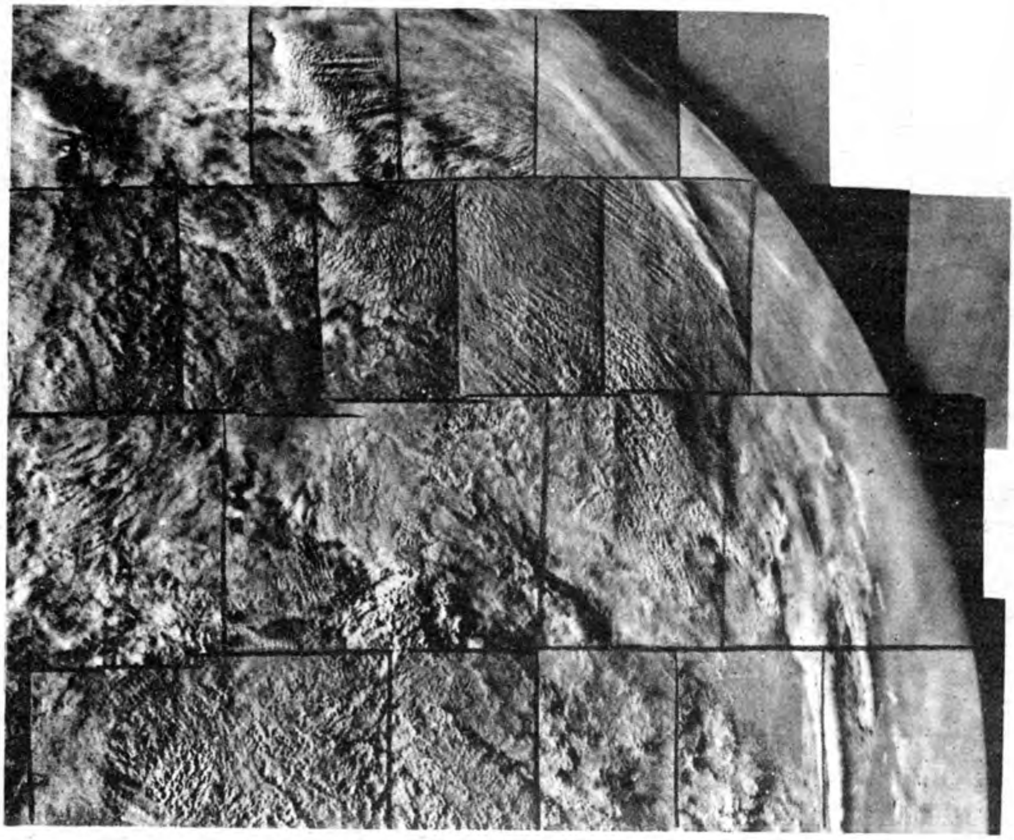
It is these low-lying regions which are commonly associated with the first signs of activity in a major Martian dust storm. For example, in 1892, 1909, 1924, 1939, 1956 and 1971 small bright yellow clouds were seen in the *Hellas Planitia -Noachis* region prior to the outbreak of planetwide dust storms. Recently a picture taken by Viking Orbiter 2 showed such a cloud more than 300 km across in *Argyre Planitia* [7]*.

Particles with quite a wide range of sizes are lifted into the atmosphere, according to spacecraft data. Grains with diameters of around 2μm might be able to stay suspended at great heights for a whole Martian year [8], although particles with diameters of around 1 μm settle within a few months [9] once storm energy input has ceased. Nearer the ground the dimensions are slightly larger (up to ~ 100 μm across).

Martian Soil – An Abode of Life?

As for the composition of windborne particles, it seems that a mixture of materials is involved. Mariner 9, not

* *This was the precursor, as in 1971, for the outbreak of a global obscuration, which the Viking 1 and 2 Orbiters were able to follow from February 1977.*



A portion of the southern hemisphere of Mars is almost completely covered by a developing global-scale dust storm. This storm is believed to have begun several days before Viking Orbiter 2 obtained these photos on 7 June 1977 from an altitude of 16,740 miles (27,000 km). The 27-frame mosaic shows an area from the equator, at top, to 50 deg south latitude and, right to left, from 75 to 150 deg west longitude. Two of the huge Tharsis volcanoes are visible at upper left as dark circular markings. The western part of the huge *Valles Marineris* canyon system stretches across the top frames just north of a mass of storm clouds. The clouds display considerable linear structure. Dark areas within the clouds are relatively clear spots, allowing localised observation of the surface.

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surprisingly, revealed spectral features attributable to silicates in its infrared scans of the Martian atmosphere [10]. Comparison with laboratory spectra has indicated the likelihood of there being present grains derived from materials resembling dacite and tholeiitic basalt (with silica – SiO_2 – content from ~ 50-70%) and of course the Viking 1 and 2 Landers have given close-up views of dunes similar in form to some types found in terrestrial deserts.

Densities of the particles are 2700-2900 kg/m^3. Limonite (a mixture of hydrated iron oxides and hydroxides, e.g. goethite; n FeO.OH where n is an integer) gives the planet its red colouration (due to the Fe^{+++} ions). It has also been claimed that a good fit to the absorption and emission features in the infrared is given by the clay mineral montmorillonite (a collective name covering $Al_2\ Si_4\ O_{10}\ (OH)_2 . nH_2\ O$ to $(Na, ½Ca)_{0.4}\ Al_{1.6}\ Mg_{0.4}\ Si_4\ O_{10}\ (OH)_2)$ [11]. Montmorillonite can form in an environment where water circulation is poor by utilising Mg^{++} ions from, for example, olivine and pyroxene, and volcanic glass, combining with alumina ($Al_2\ O_3$) and SiO_2 [12]. This is of interest in view of the now familiar volcanic features of the Red Planet. Iron oxides commonly occur in association with the clays of terrestrial soils.

Pure SiO_2 – as quartz – can contribute nothing to the nutrition of terrestrial-type life. So the possibility of any Earth-like organisms residing in an exclusively silica (i.e. sandy) soil is very remote. What is required is a set of nutrients and water (in some form or other) to allow any plant or animal to survive. The biological analyses by the two Viking Landers have failed to establish conclusively that any life is present in the soil samples taken at the landing sites (in the *Chryse* and *Utopia* Plains). Nonetheless, this does not rule out the possibility that life can exist elsewhere on the planet. At other locations the temperature range, pressure and water content of the environment might be more suitable.

Imagine an organism that could survive just below the surface in a layer of soil. Plant life on Earth requires large amounts of nitrogen, phosphorous, potassium, calcium, magnesium and sulphur,and lesser quantities of iron, manganese, boron, chlorine, copper,zinc and molybdenum [13]. Chemical assays by the X-ray fluorescence spectrometers of the Vikings have shown that pyroxenes (e.g. $Fe_2\ Si_2\ O_6$), montmorillonite and montronite (another clay mineral) are probably present in the Martian soil [14]. But relatively few chemical elements have as yet been definitely found.

If clay minerals like montmorillonite do exist on Mars [11, 14], there are enhanced possibilities for the existence of life. The ability of clay to store liquid water is well known. Vast amounts of frozen water are now thought to be present in the permafrost region at depths of up to about a kilometre below the Martian ground. The morning fogs seen for a long time from Earth [3] and now – in striking clarity – on Viking orbiter photographs [15] give evidence that evaporation of water does occur. Upward motion of gaseous water might lead to entrapment of moisture in clay near the ground surface, where it would most probably freeze. On Earth, soil with a high percentage of clay restricts the amount of water available to plants and this point must be borne in mind in the case of Mars. In the absence of oxygen ferric oxide, $Fe_2\ O_3$, is liable to be reduced to biologically harmful ferrous oxide, FeO. But the apparently large amounts of limonite in the Martian regolith at least suggest that this has not happened (ferrous ions give a blue colour to soil). Although soil colour can only be taken as a very rough guide to iron content ferrous ions are probably not present in abundance. $Fe_2 O_3$ is an essential nutrient for plants. Certain terrestrial microbes are able to oxidise and reduce the iron in the soil as part of their metabolic processes.

It is conceivable that very small bacteria could subsist in the particles making up the Martian soil. They would be shielded from harmful ultraviolet radiation and might be able to draw on water stored in the sheetlike structure of clay minerals, and utilise elements such as calcium which can also be part of the structure. Clays comprise the smallest known crystals – less than 2μm across. The majority of terrestrial soil bacteria are less than 0.5μm long, so size would not be a problem. Larger organisms such as protozoa could dwell in larger particles – when clay becomes sufficiently wet it swells enormously.

Transport of Life

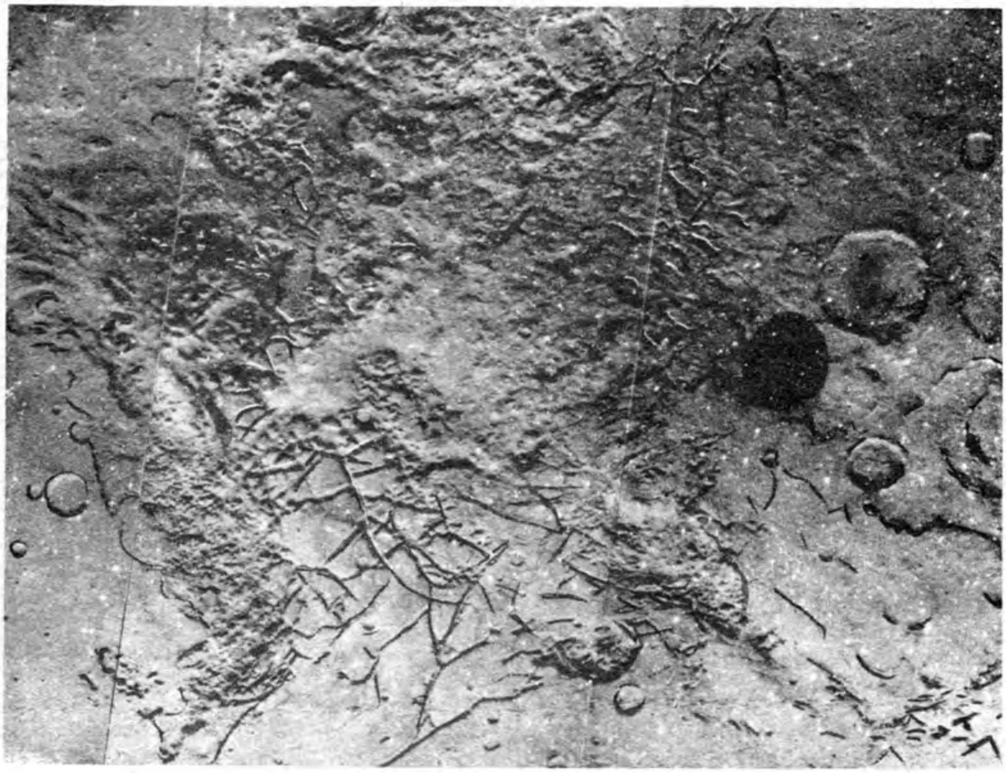
Any organisms inhabiting the small particles (say 1 - 100 μm across) comprising the Martian soil would become liable to dispersion by wind during a dust storm. Thus such organisms would have to be able to survive possible wind buffeting and impact with the surface (having been raised into the air) as particles deflate and saltate. This is an addition to the capability to exist in such an oxygen-poor atmosphere (concentration $\simeq$ 0.1% near the surface) with penetrating ultraviolet radiation in comparative abundance due to the absence of an atmospheric ozone layer, and low temperatures in which liquid water could barely exist (the maximum average temperature at the mean surface level of Mars is about 240K; the triple point pressure of water at 273.2K is 6.1 mb). Taking a surface pressure of $\sim$ 5 mb, the minimum frictional velocity necessary to initiate movement of a 250 μm diameter grain – rather large for Mars, it seems – is about 14 km/h [4]. The momentum of the moving particle would be approximately 8.4 x 10^{-8} kg m/s if it were a siliceous body carried along with the wind velocity. The effect of impact with the ground would be very small [16]: quartz is very tough; but very much softer materials such as dry snow will not suffer appreciable stresses on impact with a hard surface even in high winds. The smaller the body the smaller the stress caused by impact at a given velocity.

Once the particles with their living passengers have become airborne their flight times will depend on a number of factors. These include the frequency of collisions between particles, and between particles and the ground. During the 1971 dust storm the Martian atmosphere was isothermal at about 230K up to altitudes of 15-20 km [6], – due to dust absorbing solar radiation and warming the atmosphere.

When energy input to a storm has ceased particles are able to settle under the action of gravity. Stokes' law or the Stokes-Cunningham equation (for particles with effective radii greater or less than the mean free path of the gas molecules, respectively) can be used to find the settling rates in a still atmosphere [9]. Coarse sand-sized objects (about 2 mm across) will fall to the ground in about 10 seconds from the top of the boundary layer of Mars. Considerations of shearing winds at different altitudes will give lower values for these rates – if a shear is present this will assist further in the lateral transport of dust. A body 200 μm across will fall to the ground in about a Martian day [17] But recent Viking analyses lead to the estimate that soil particles are no more than 100 μm across and this would somewhat lengthen the settling time. The Martian atmosphere took about three months to be cleared of large particles when the 1971 storm was dying away. Smaller particles (of about 5 μm diameter) remained suspended in the atmosphere some two months after dust raising had practically ceased.

Repeated raising and settling of dust as storms come and go could lead to eventual global settlement of the life forms existing in the windborne sediments. Whether they would survive in their new environs would of course again depend on the physical and chemical conditions prevailing during the flight and, much more importantly, in the new region. Another factor to consider is that deflation of surface material by winds could expose 'settled' organisms to potentially harmful ultraviolet radiation.

Polar temperature might prove too harsh for life, as might the tops of volcanoes (where the pressures can drop to $\lesssim$ 2 mb and temperatures to $\lesssim$ 180 K). Conditions in basins near the equator might be best; pressure and temperature being higher there so that liquid water might exist. Future



AFTER THE STORMS. One of the clearest pictures of Mars taken by Viking Orbiter 1 since the planet was enveloped in dust storms that began in February 1977. The region contains chaotic terrain along the Martian equator. It is near the head of *Area Vallis*, a major channel leading to *Chryse Basin*, site of the Viking 1 Lander. Black spot is the Martian moon Phobos passing beneath the spacecraft. When the picture was taken Orbiter 1 was 8,500 miles (13,700 km) above the *Margaritifer Sinus* region and Phobos was 4,260 miles (6,700 km) from the spacecraft.

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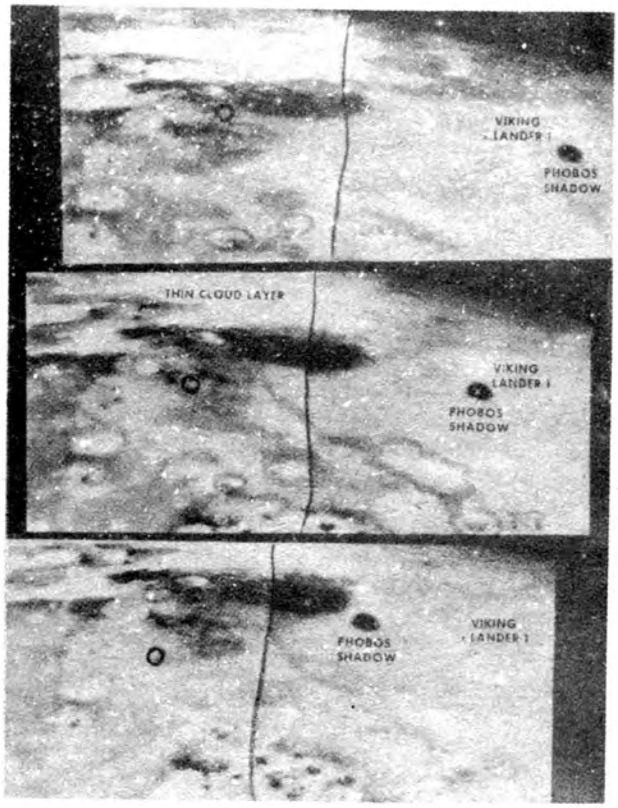
biological missions to Mars might do well to search in *Hellas*, for instance. Natural selection would operate to ensure that only the hardiest organisms survived. Just as some plants and animals on Earth have spread from their place of origin to other parts by water transport, the Martian winds might so operate now or they may have operated in the past.

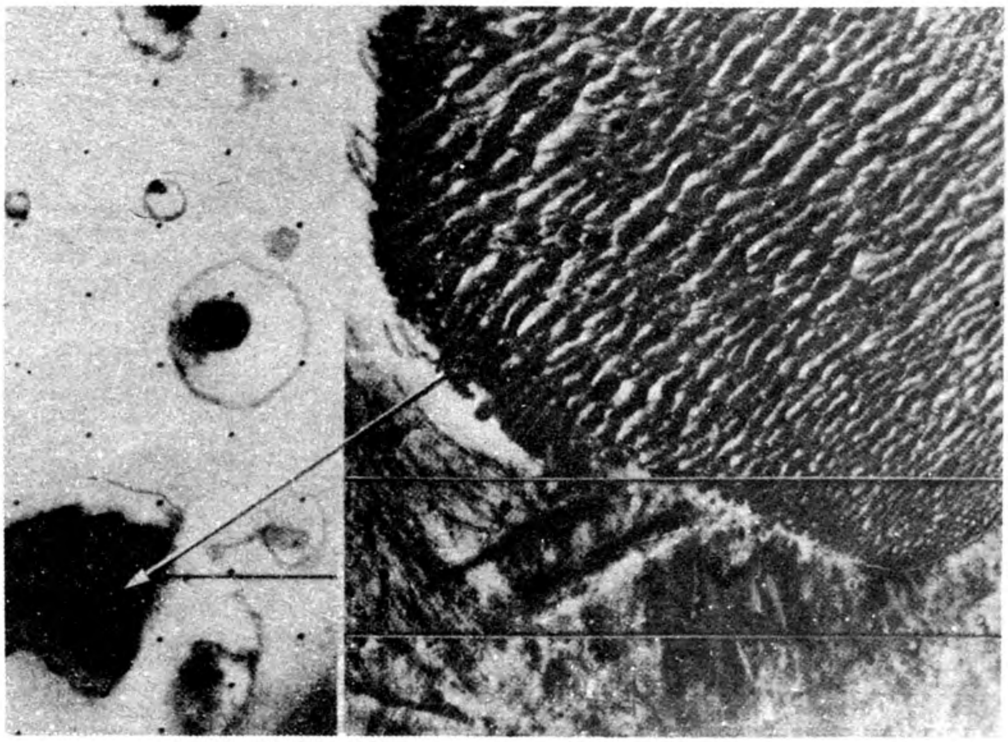
Viking Lander Data

The Landers have made chemical analyses of Martian soils and found, by X-ray fluorescence measurements, that silicon, calcium and iron are plentiful. Substantial amounts of sodium and sulphur are also present in the *Chryse* and *Utopia Planitia* samples and there may be barium too [18]. Thus not all of the elements needed by terrestrial flora have, so far, been detected.

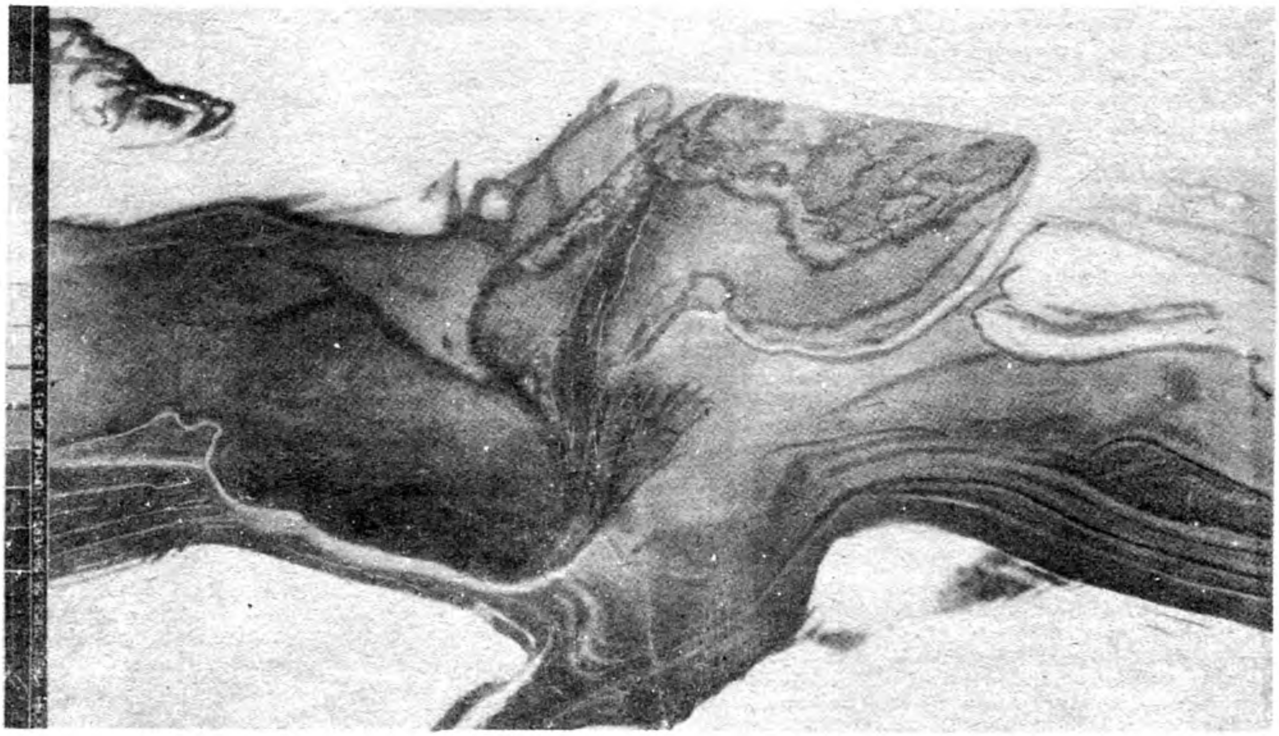
Ideas on the presence of clay particles have been reinforced, as mentioned earlier, by the probable detection of montmorillonite and montronite. Pyroxenes, hematite (Fe_2O_3) and magnetite (Fe_3O_4) have also been found by the Viking Landers. Limonite is suggested, too, from surface



Top right. These Viking Orbiter 1 pictures are part of a new experiment to locate the position of Viking Lander 1 on Mars using shadows of the Martian moons, Phobos and Deimos. The photos are the first (bottom), middle, and last (top) in a 40-picture series of the shadow of Phobos taken during a three-minute period. The shadow, about 56 miles (90 km) long, moved about 220 miles (350 km) from west to east across the surface of Mars. At the same time Viking Lander 1 took pictures as the shadow of Phobos crossed over it. Careful timing and detailed processing of these and similar Phobos/Deimos shadow pictures will allow scientists to locate the Lander within 0.6 mile (1 km); combining the moon photos with other data will allow the lander's position to be fixed within about 650 ft. (200 m). *Lunae Planum*, a heavily cratered plain on Mars, is at the left in the pictures. The crater Sharonov, 93 miles (150 km) in diameter, is at the top. *Chryse Planitia*, where Viking Lander 1 touched down on 20 July 1976, is at the right.



Right. CRATER OF DUNES. Evidence of large scale wind erosion on Mars is visible in the Mariner 9 photo at right. It shows a dune field of loose material in the floor of the 150 km (93 miles) wide crater in the *Hellespontus* region. The field appears as a dark spot in the wide-angle view of the crater (arrow). JPL programme scientists said the similarity in size and direction of the individual dunes indicates they were formed by strong winds blowing from a consistent direction, in this case from the south west.



FROSTY SCENE near Mars' north pole shows the region in mid-summer when the seasonal carbon-dioxide polar mantle clears to reveal water ice and layered terrain beneath. Three black and white pictures taken on 26 October 1976 by Viking Orbiter 2 through red, green and blue filters were computer processed to produce this composite, which covers about 60 by 30 km (37 by 18 miles). Contact between ice and ground at top occurs at the brink of a scarp about 500 metres (165 ft.) thick. Regularity of the layers suggests relationship to periodic changes in Mars' orbit – a relationship that, on Earth, may be at least partly responsible for ice ages. Mars' changing orbit may affect frequency and intensity of global dust storms, and hence the amount of material from which sedimentary layered terrain forms.

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spectral measurements. Thus the idea of windborne life is not completely ruled out.

So far the presence of life on Mars seems unlikely, but whether or not any is present now, the mechanism of global transport of small organisms by aid of windborne grains could have taken place in the past. Conditions may well have been more favourable [19] for the existence of life many thousands of years ago, as indicated by the number of Martian features probably produced by running water.

Future landings on the Red Planet will lead to improved knowledge of present (and past) environmental conditions and whether they are conclusive to biological activity.

Acknowledgement

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UNITED STATES MISSILE RANGES: ORIGIN AND HISTORY

By David L. Skinner

Introduction

The immediate ancestor of missile testing facilities is the artillery proving ground. This was the result of surface-to-surface missiles, especially those of the liquid propellant variety, being developed to augment or supercede cannon-type artillery. The increase of range made possible by surface-to-surface missiles and the increase in altitude attainable by sounding rockets, were the primary causes of the growth and development of missile testing facilities.

A missile testing facility without instrumentation would be merely a patch of land or water. Proving grounds became ranges when on-board instrumentation and telemetry were added to the missiles being tested. Missile ranges thus include the launching facility and instrumentation needed to both track a missile and monitor its on-board systems during flight. The developmental history is therefore crucially a history of instrumentation at facilities which have met that requirement.

Range Instrumentation

Missile range instrumentation can be divided into four basic types: tracking, on-board instrumentation and telemetry, impact detection, and data recording and reduction. Data recording and reduction involves an accurate timing scale, communications between the various data recording sites, and calculation machines for accuracy and efficiency in data reduction. Data once reduced must then be displayed for real-time and post flight analysis. Instrumentation can provide information by either recording the data in flight and recovering the recording device, or by the use of radio telemetry to transmit the data during flight for recording on the ground. Radio telemetry was first developed in 1925 by Professor Pyotr A. Moltchanoff of Slutsk, Siberia, who tested the device on a balloon [1]. Radio telemetry permits the use of sea ranges for missile testing without the difficulties involved with missile retrieval. Tracking instruments, the other source of data for recording and reduction, take varied forms which are either optical or electromagnetic by nature. Electromagnetic tracking began with Radio Acquisition and Ranging (RADAR) which can be traced to 1922 when A. H. Taylor and L. C. Young of the United States Navy noticed the effect of a ship passing through a high frequency radio wave transmission [2].

The data that is recorded and reduced is applied to two major uses. One is the immediate use of tracking information for range safety. The compilation of a real-time state vector from position and velocity data allows impact prediction. This permits missile destruction by ground-to-missile telemetry if its actual trajectory and designed trajectory differ substantially, and especially if populated areas are threatened. The second use of the reduced data is in post-flight analysis to perfect the missile system.

CAPE CANAVERAL as observed by an Earth Resources Technology Satellite. Original is a colour composite taken about 11 a.m. local time on 6 September 1972 from an altitude of 560 miles (910 km).

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Congreve and Goddard

The first use of a designated area for testing missiles was at Woolwich Arsenal, an artillery proving ground in England where Sir William Congreve began his experiments in 1791 [3]. This first missile proving ground transformed earlier 1,000 yard bombardment rockets into the famous Congreve rockets, the larger of which had ranges of 5,000 yards, a range not to be exceeded by rockets until after World War I. This is despite the fact that William Hale in the interim between Congreve and Goddard contributed spin-stabilisation to rocketry. Hale's rockets, however, did not exceed the 5,000 yard range of the larger Congreve rockets [4]. The testing technique used by Congreve resembled the artillery method of launching several rounds for accuracy, making a correction, and firing several more rounds for comparison. At this early date spyglasses were perhaps the only instruments involved.

Dr. Robert H. Goddard initiated the development of a liquid propellant rocket at Clark University at Worcester, Massachusetts. In these investigations Mrs. Goddard operated a Ciné-Kodak motion picture camera [5] in the first historical example of data-recording optical instrumentation. The devices used at Worcester also included an ordinary theodolite and "recording telescope" to determine missile altitude, as the first historical examples of metric optics [5].

"Metric optical instrumentation is photogrammetric, i.e., precise measurements of length are made against imagery recorded on film or glass plates" [6].

Timing was provided by a stop watch [5]. These devices were more than adequate to measure the 41 ft. altitude of the first liquid propellant rocket launched on 16 March 1926 [4].

On 17 May 1929 Goddard launched the first rocket with on-board instrumentation, a parachute-recoverable barometer photographed by a camera when the rocket reached its zenith. To avoid densely populated areas and to have maximum favourable weather, Goddard moved his experiments to Mescalero Ranch near Roswell, New Mexico, in the 1930's where the camera and barometer were replaced by a barograph. By definition since radio telemetry was lacking, both facilities remained only missile proving grounds. The highest altitude reached by a Goddard rocket at Mescalero Ranch was between 8,000 and 9,000 ft. [5].

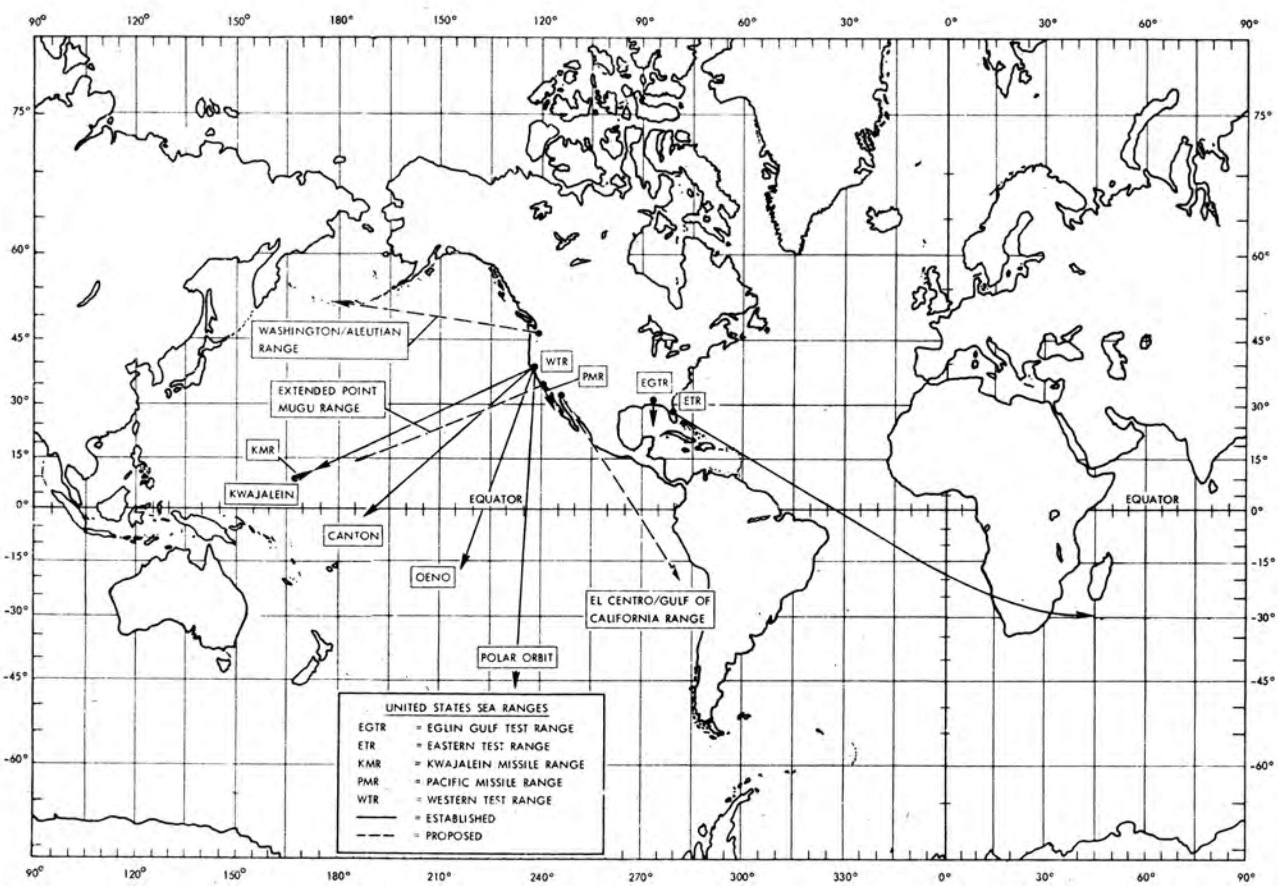
Peenemünde

The next major contributions to range instrumentation occurred at the German missile testing facility at Peenemünde, established in the spring of 1937 [4]. The German Army Weapons Department used Peenemünde to develop the 200-mile range liquid propellant rocket called the V-2, also known as the A-4. The first missile launched at Peenemünde, the A-3, had a maximum altitude of 7.5 miles and a maximum range of 11 miles [7]. To test the A-3, Peenemünde was equipped with theodolites and various cameras. These were similar to Goddard's devices, but had come from the Kummersdorf Artillery Proving Ground 17 miles south of Berlin and its launch facility on the Island of Oie in the Baltic where the forerunners of the A-3, the A-2 and A-1, were developed. Timing apparatus was adapted from previously existing high-speed mechanical, electromagnetic, and photographic devices.

"Time was measured in terms of vibration periods of a tuning fork which were recorded together with screen signals by means of mirror oscillographs on moving photographic paper, or records were made by printing devices on ticker-tape recorders, by sparks recording on waxed paper moving at a known speed, or by the old familiar Boulengé chronograph in which marks are made on a rod falling under the influence of gravity" [8].

One new device did emerge at Kummersdorf and Oie however; the phototheodolite or plate camera originally used for artillery ballistics research [8].

The expected range of the V-2, twenty times the maximum range of the A-3, promoted the development of three important new pieces of range instrumentation at Peenemünde. The first was the cinetheodolite, a motion picture camera combined with the azimuth and elevation measuring surveying instrument [8]. The second was a two-way Doppler radar system which provided position, velocity and acceleration data once the V-2 left the visual range limitations of the cinetheodolites. The Doppler system consisted of a Wurzburg antenna [9] which transmitted a 23 MHz signal to a transponder on-board the V-2. The transponder amplified, doubled the frequency, and retransmitted the signal for ground station reception and analysis. The third, and most important contribution to range instrumentation was the first on-board engineering measurement and telemetry system, which evaluated the performance of the V-2 and transmitted the data back for recording. The telemetry



system consisted of a commutator on-board the V-2 which sampled each of twelve useful channels plus a calibration channel 500 times per second. The signals were then transmitted using amplitude modulation for ground reception where the decoded results were recorded on one or more six-channel Siemens Universal Oscillographs. A unique method to manually reduce telemetered data recorded on oscillographs was used at Peenemünde [8].

> "The receiver was set up in a lighthouse tower, and the graph allowed to hang down the central hole of the circular staircase. The technicians would then clamber up and down the steps in order to read the applicable portions" [10].

According to Leslie Simon "without the telemetered measurements the V-2 could not have been developed" [8]. The use of on-board instrumentation and radio telemetry transformed Peenemünde into the first missile range.

American Missile Proving Grounds

During World War II the United States first began to build upon the Goddard instrumentation technology. In the east, missile proving grounds were established at the artillery testing facilities at Dahlgren, Virginia and Indian Head, Maryland [11]. By 1944 these two facilities had been replaced by the Alleghany Ballistics Laboratory (ABL) at Pinto, West Virginia [4, 11]. In the West, the military missile effort utilised the Mojave Antiaircraft Artillery Range at Camp Irwin, California which was soon replaced by the more famous adjacent Goldstone Lake [11]. The need for additional missile testing facilities led to the establishment of two new missile proving grounds in the summer of 1943 at the Marine reservation at Camp Pendleton, California and the Naval Ordnance Test Station (NOTS) at Inyokern, California [11]. During this period Dr. Bowen of the California Institute of Technology (CIT) used the facilities at Goldstone Lake and NOTS [6] to develop the first ribbon-frame device, the CIT Acceleration Camera [11].

The so-called Goldstone Range was typical of the better equipped American missile proving grounds during this period. The dry lake bed had premeasured distances marked every 500 ft. which permitted observers in spotting towers equipped with theodolites to easily locate the missile. The exact impact point was determined by plotting the data from two or more spotters on a range map called a "plotting board". Post flight data came from surveillance and documentary motion picture cameras and the new CIT device. The missiles launched during World War II at facilities like Goldstone usually had ranges less than five miles since they were seldom of the surface-to-surface missile variety [11].

However, the V-2 caused the Army to initiate the Ordnance California Institute of Technology (ORDCIT) Project to develop long-range surface-to-surface missiles in late 1944. As a result of ORDCIT, two major additions to United States missile testing facility instrumentation occurred at the newly created Hueco Range at Fort Bliss, Texas in the spring of 1945. The first was the World War II aircraft-detection SCR-584 mono-pulse radar tracking system which was used to test 17 ORDCIT Private-F research rockets launched between 1 April and 13 April [1]. The second addition, which made the Hueco Range the first United States missile range, was the use of radio telemetry to report the forces acting on a model airfoil carried by a High-Velocity Aircraft Rocket [12].

White Sands Missile Range*

Adjacent to the Hueco Range, the White Sands Missile Range was formed for the same two reasons Goddard picked his New Mexico location – areas of minimum population and maximum good weather. This addition of land and facilities was the result of ORDCIT evaluations of the range capabilities of the V-2 [14]. The two ranges, though separate, worked together on missile testing under Army control.

When Operation Paperclip brought the German rocket scientists to the United States, the Peenemünde range instrumentation was also transferred. Yet, within a year of the war's end United States missile ranges had already modified, and gone beyond, the two World War II technologies. White Sands in 1946 contained examples of each type of optical tracking system, two of three types of radar systems, a more compact telemetry system, the first missile impact detection system, as well as an early attempt at calculation machines for data reduction and various mechanisms for displaying the reduced data.

Tracking metric optics change the exterior orientation of the camera during the data gathering process [6]. The only sorts of tracking metric optics available immediately after World War II were confiscated Peenemünde Askania cinetheodolites and makeshift American Akeley Bomb Scoring Theodolites which were designed and manufactured by the Mitchell Camera Corporation. In the area of fixed metric optics, the opposite of tracking metric optics, the ribbon-frame CIT Acceleration Camera was joined by the descendant of the German phototheodolite, the Trajectory Plate Camera. Surveillance motion picture cameras originally used by the Goddards had evolved by now into the Eastman Type-III and Western Electric Fastax high speed cameras. Even the first tracking telescope emerged at White Sands. The telescope was mounted on an electrically driven gun carriage and was pointed by an observer manipulating 20-power binoculars [15].

The frequency of the two-way Doppler radar system used on the V-2 at Peenemünde was increased from 23 to 36 MHz by the Ballistics Research Laboratory (BRL) at the Army's Aberdeen Proving Ground in Maryland and renamed DOppler Velocity And Position (DOVAP). DOVAP and the SCR-584 mono-pulse radar were the chief radar tracking devices at White Sands during the post-war period. A one-way Doppler system for short range measurements, called the Sperry Doppler Velocimeter Model-10 was also used at White Sands. The one missing radar device for range instrumentation was the phase-comparison radar. The V-2 launched at White Sands on 17 December 1946 which set an American altitude record of 115 miles was successfully tracked over its entire trajectory using the SCR-584 coupled with the AN/APN-55 beacon on-board the missile. By comparison, the one-way SCR-584 was limited to tracking the smaller WAC-Corporal, which did not carry a beacon, for the first 18 miles of its trajectory [16].

The tracking data of the SCR-584 one- and two-way mono-pulse radar systems were the primary sources of real-time information. The potentiometer voltage was displayed on a Plan Position Indicator (PPI) Scope or an A-Scope while it was also translated and displayed on two automatic plotting boards, the MC-627 and T14E, which replaced the manual Goldstone model [16]. The PPI scope represents a circular map of the area around the radar facility on which a line indicating the direction of the radar beam radiates outward from the centre of the display and rotates with the angular velocity of the actual antenna. As the line sweeps around the screen, light spots or "blips" representing targets appear at the proper range and direction on the ground map. The A-scope consists of a horizontal line on a cathode ray oscilloscope. The line will contain triangular deflections representing the transmitted pulse and the returning echo.

* *The original name for the White Sands Missile Range established 13 August 1945 was the White Sands Proving Ground, a name it would hold throughout the 1950's [13].*

The distance between the two deflections represents the range of the target [17]. The MC-627 was originally designed to plot an aircraft ground-track on a long-range remote-controlled bombing run. The T14E was originally designed for plotting altitude *versus* distance from the launcher on one plotting board and the ground-track on a second board for mortar shell tests. Both were manufactured by the Bell Laboratories. A third type of plotting board was used exclusively at NOTS [16].

The plotting boards were crude examples of analog computers and their accuracy was correspondingly low. One post-flight general purpose analog computer with adequate accuracy called the 200-Foot Slide Rule was being used in 1946 at the Hueco Range. It could attain an accuracy of one part in 20,000 by printing the scales on reels of 35-mm film for comparison [18]. Yet, in terms of accuracy the digital computer was far superior to its analog counterpart. The most primitive digital computers were the International Business Machines (IBM) electric adding machines which had been available since December 1944 at BRL at Aberdeen and at the Naval Proving Ground at Dahlgren. They were hampered by large errors due to manual transcription of data, to and from paper, between each calculation step. By the spring of 1946 some of this error was being reduced by the use of the new IBM punch card machine, the 603 Electronic Calculator, which could perform a series of calculations without manual intervention. At Dahlgren the IBM punched card machines were augmented by the electro-mechanical Harvard Mark-II [19] which could completely solve complex mathematical problems by a set of instructions given to the machine by a punched tape. This machine and its vacuum-tube counterpart, the first electronic digital computer, the Electronic Numerical Integrator and Computer (ENIAC), developed at Aberdeen were not used at American missile ranges during this period despite origins in ballistics research [20].

Data recording from the SCR-584 and DOVAP radars at White Sands for processing by the electronic adding machines and the IBM punch card machines was accomplished by photographing the needle deflections on the display dials at precise time intervals actuated by a timing signal continuously broadcast during the missile's flight. The Hueco Range had a slight modification on this system whereby the data was not photographed, but rather converted to type-like printing on tape. This primitive non-magnetic "tape recorder" was another product of the Bell Laboratories [16].

Impact detection was accomplished by radar, a technique developed at artillery proving grounds. The splash of soil and dust upon impact made a sizeable target. The original impact detection system at White Sands was the AN/MPG-1 pulse radar [16].

Telemetry had been added to the WAC-Corporal after tests on the WAC-B in December 1946 [21], thus building on the early Hueco and bulky V-2 efforts. The WAC-Corporal at White Sands was the namesake of the Private-F at the Hueco Range. Both were by-products of the ORDCIT Project. The WAC-Corporal telemetry had only five channels [21] as compared with twelve on the original V-2 system, but fitted the 25 pound [1] weight limit of its carrier rocket.

By 1950 the United States was testing missiles at seven ranges, the largest of which was White Sands in New Mexico operated by the Army. Another Army facility was the adjacent Hueco Range at Fort Bliss, Texas. The National Advisory Committee on Aeronautics (NACA) opened a range in July 1945 called Wallops Station at Wallops Island, Virginia which was inherited by the National Aeronautics and Space Administration (NASA) in 1958. The Navy retained the World War II developed Naval Ordnance Test Station at Inyokern, California and added the Naval Air Facility at Point Mugu, California in December 1945. The new facility, renamed Naval Air Missile Test Center (NAMTC) in July 1946 would eventually be the headquarters of the Pacific Missile Range beginning on 16 June 1958. The Army Air Corps, which became the Air Force in 1947, operated a range at Eglin Field (Eglin Air Force Base) in Florida after the war which eventually became the Eglin Gulf Test Range. The Air Force also operated a range at Holloman Air Force Base, New Mexico which, like Hueco, was adjacent to White Sands. White Sands range jurisdiction would include Hueco and Holloman by 9 August 1952 [22, 13, 23].

Because of its size White Sands was at the forefront of range instrumentation technology during the period from 1945 to 1950. This range, 100 miles in length, was the only one able to handle the V-2 with its phase-comparison DOVAP radar. However, not even White Sands could contain the V-2 if its full 200 mile range were utilised.

Eastern Test Range*

On 29 May 1947 a V-2 went out of control, travelling only 47 miles, but landing near Juarez, Mexico [14]. This flight together with the size constraints of America's largest missile range expedited the recommendations of the Committee on Long-Range Missile Proving Grounds of the Joint Research and Development Board of the War Department [26]. Within a month the committee responded with four proposed locations to permanently solve the missile range size problem.

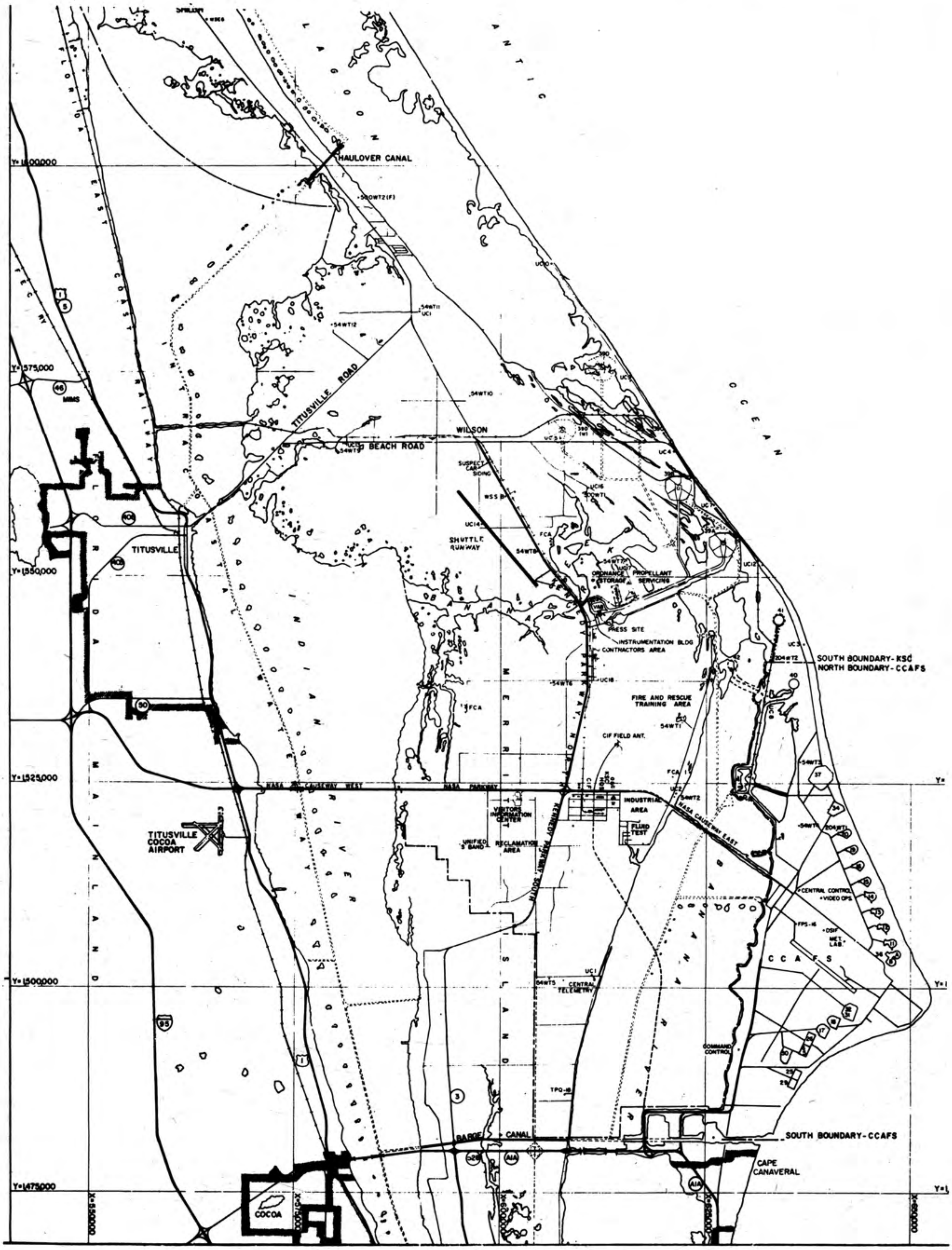
To avoid impinging on populated areas, a consideration which originally brought Goddard to New Mexico, the committee used the Peenemünde approach – sea ranges. The main problem with sea ranges which would eventually extend for thousands of miles was the location of permanent tracking facilities. Although ships could be used in open areas, the committee preferred chains of islands and other land masses at this early point in range history. The other Goddard consideration, favourable weather, also played a decisive role.

The selection of a launch facility in Washington State with tracking facilities along the Aleutian chain was relegated to fourth choice because of its adverse climate, while the possibility of expanding the Naval Air Missile Test Center at Point Mugu, California across the Pacific was relegated to third choice because of the lack of nearby land masses for tracking sites [27]. This left the first choice, a launch site at the El Centro, California Naval Air Station with tracking facilities on either side of the flight path down the Gulf of California to the South Pacific; and the second choice, a launch site on Cape Canaveral 18 miles north of the already existing Banana River Naval Air Station with tracking facilities on the British owned Bahama Islands. The first choice was abandoned after negotiations with the President of Mexico in December 1947 failed to secure sovereignty rights for tracking stations [26]. Great Britain was more cooperative, and the Florida choice became the first long-range proving ground. The range of the missiles being tested may have caused the selection of a sea range, but the need for tracking stations provided the specific key for its location.

The Eastern Test Range was not the first American sea

* *The Eastern Test Range was called the Long Range Proving Ground from its first launch, a V-2/WAC-Corporal, on 24 July 1950 through the end of 1951. The unofficial but nevertheless effective title from 1952 until 30 April 1958 was Florida Missile Test Range. When the Pacific Missile Range was formed on the west coast, the name Atlantic Missile Range was given to the east coast facility. Shortly after the National Range Division was formed on 15 May 1964 the name was changed to its present designation [24, 25].*

JOHN F. KENNEDY SPACE CENTER



range. That distinction was held by Wallops Station in Virginia. Wallops Station, a range by definition since it used telemetry, however, was not the first American missile test facility using the oceans. That distinction was held by the missile proving ground at Camp Pendleton, California [11].

The first year of launchings at the Eastern Test Range was without the assistance of telemetry, and by definition the Florida facility was not yet a range. The first two launchings from the new facility in July 1950 were V-2/WAC-Corporals as part of Project Bumper. The only instrumentation available at that time was temporary mono-pulse radar and optical tracking on-board two Navy destroyers, the USS Sarsfield and USS Foss. From July 1950 to June 1951 small Lark missiles were also launched using only Cape Canaveral based tracking. Finally, on 20 June 1951 the facility acquired its first downrange tracking station and by 31 December 1951 the first telemetry system was ready for use [28, 29].

The initial development of the Eastern Test Range was accomplished with winged missiles. The first use of Jupiter Inlet and Grand Bahama, which expanded range coverage to 200 miles, was accomplished with the launch of the first Matador missile on 20 June 1951. Eleuthera Island at 300 miles distance was soon added to the Matador testing programme. On 26 November 1955 a Snark was the first missile to use San Salvador, Mayaguana, and Grand Turk providing 700 miles of coverage. On 5 December 1956 Dominican Republic, Puerto Rico, and St. Lucia were added on another Snark flight stretching the range to 1500 miles, enough to handle Intermediate Range Ballistic Missiles (IRBM's). On 31 October 1957 yet another Snark made the first flight to Ascension Island opening the range to Intercontinental Ballistic Missiles (ICBM's) at 5,000 to 6,000 miles. The final addition, however, was made by a ballistic missile, an Atlas-D, which used the Pretoria, South Africa station on its flight to the Indian Ocean on 20 May 1960 opening the range to extended-ICBM's at 9,000 to 10,000 miles [29]. Optical systems provided a majority of the testing data during this period, due to the low altitude of the winged missile trajectories, but this trend changed in favour of radar tracking and telemetry as the high-arching ballistic missiles became predominant. The extensive use of radar and telemetry in the development of ballistic missiles at the Eastern Test Range matched a similar trend at Peenemünde where statistics indicate that 80% [30] of all V-2 flights were made without optical equipment.

The expansion of a range from one hundred to several thousand miles was accomplished through the development of new communications and timing techniques. The first 1,250 miles of the system to Antigua were connected by submarine cable while the outermost stations were reached by radio. Timing at the new range was accomplished by several independent signal generators which were synchronised with the US Naval Observatory, also by radio.

Another development in range instrumentation technique was the extensive use of ships and planes to fill the large gaps in the range especially between St. Lucia and Fernando de Noranha which are nearly 2,500 miles apart. The large gaps were initially filled by small picket ships, which were used to record incoming telemetry data. Six FS class picket ships were introduced for the Snark Program flights to Antigua and Ascension in October 1957 [6]. The St. Lucia-Fernando de Noranha gap happened to be located at the high point of an ICBM trajectory and thus telemetry reception was the priority requirement. After two years these picket ships were deactivated and replaced by instrumented aircraft. Instrumentation size and weight decreases, paralleling those occurring in computer technology, made this possible. Although an individual plane cannot carry the instrumentation of a ship, its use in remote areas is justified by its 10-to-1 increase in area coverage [31]. By 1968 eight modified C-135 [28] jet transports comprised the fleet of Eastern Test Range aircraft.

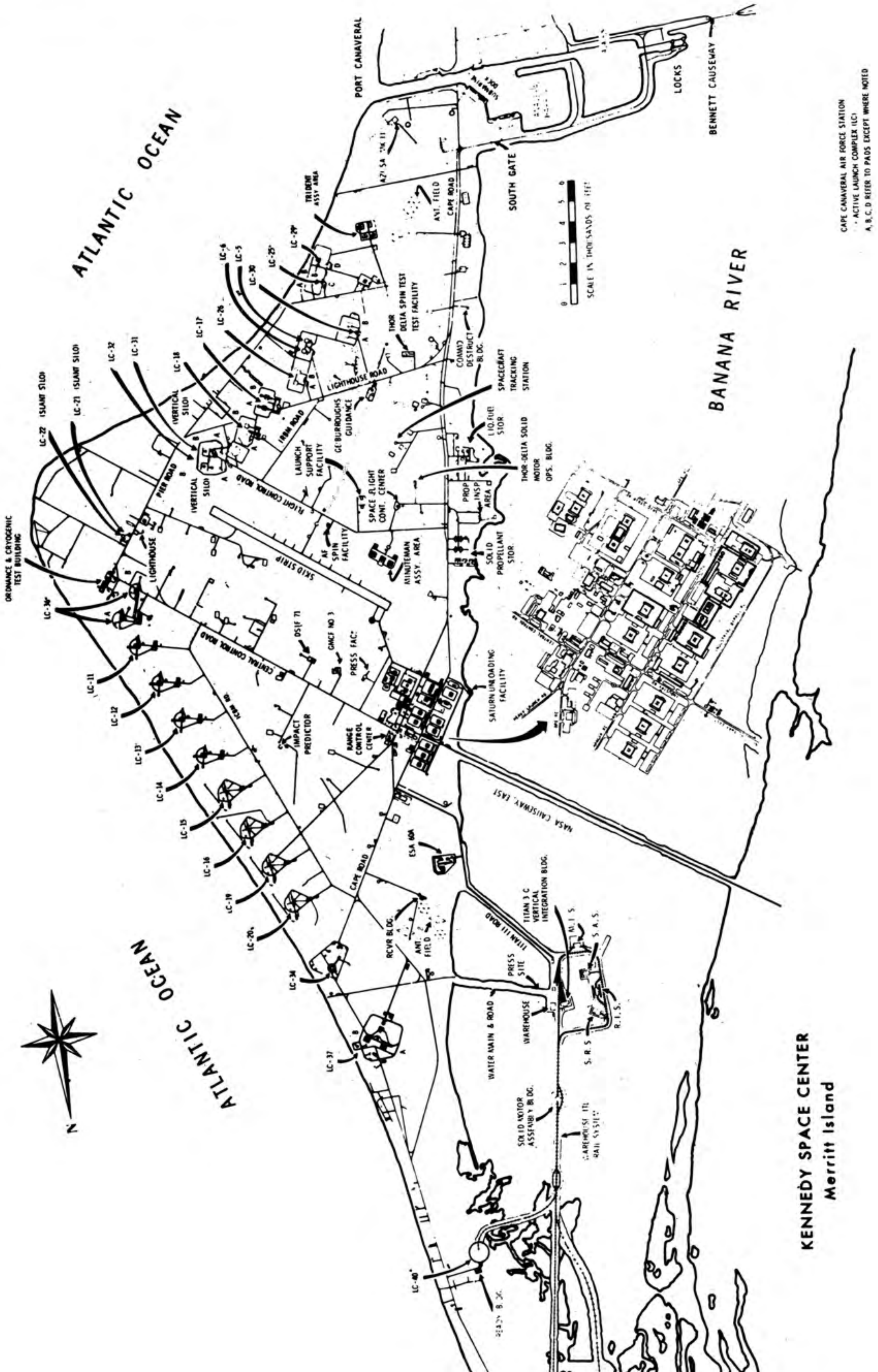
In the reentry areas at Grand Turk, Antigua, and Ascension instrumented aircraft and ships were used to augment the island based tracking and telemetry system. The first tracking and telemetry ship, the *Twin Falls* became operational on 30 October 1960 in support of the Pershing Program [6]. Tracking necessitated a precisely known position. When weather permitted, ships were located for tracking purposes by the star-tracking Ships Inertial Navigation System (SINS) which could be replaced by the older LOng RAnge Navigation (LORAN) system, a long range variation of the SHOrt RAnge Navigation (SHORAN) system of radio triangulation used at White Sands. LORAN and SHORAN involve a pulsed transmitter, a receiver at the location in question, and two transponder beacons at other known locations. Later versions of LORAN and SHORAN were the LOng Range ACcuracy (LORAC) and HIgh precision RAnge Navigation (HIRAN) systems, respectively.

Optical instrumentation at the Eastern Test Range began with transplanted White Sands devices. Tracking metric optics included later versions of the Askania and Mitchell cinetheodolites. The fixed metric CIT Acceleration Camera, sometimes referred to as the CIT-1 Bowen-Knapp, was replaced by the Clark and Hulcher ribbon-frame devices. These led to the CZR-1 Bowen-Knapp which has dominated that area of fixed metric optics ever since. The White Sands Tracking Plate Camera was soon transformed into the BC-37 which was eventually replaced by the BC-4. The BC-4 plate cameras at Grand Bahama, San Salvador, Grand Turk, and Puerto Rico provided extremely accurate acceleration data in the late 1950's by photographing night launched missiles carrying strobe lights. The White Sands Telescope had a counterpart at Cape Canaveral in the Gun Sight Aiming Point (GSAP) cameras which were eventually developed into the Intercept Ground Optical Recorder (IGOR) and Recording Optical Tracking Instrument (ROTI) [6, 32, 33].

Mono-pulse radar at the Eastern Test Range began with the World War II SCR-584 Mod-I which had a range of 190 nautical miles at a frequency of 2700-2900 MHz. The development of the SCR-584 Mod-II began in 1953 with a range of 400 nautical miles at the same frequency, and became operational at Grand Bahama in July 1955. That same year work on its replacement, the AN/FPS-16, with a range of 500 nautical miles at a frequency of 5400-5900 MHz began. The first operational AN/FPS-16 was installed at Patrick Air Force Base, formerly the Banana River Naval Air Station, on 27 November 1956. In the 1960's the AN/FPQ-6 and its portable equivalent, the AN/TPQ-18, obtained a range of 32,000 nautical miles by increasing the AN/FPS-16 antenna size from 12 ft. to 29 ft. in diameter, and operating at the same frequency [27, 28].

In the area of Doppler radar at the Eastern Test Range, DOVAP was not used until the Redstone was developed. The first DOVAP equipment arrived at Patrick Air Force Base on 8 March 1954. The problems with DOVAP were ionospheric refraction due to its low frequency (36 MHz) and second harmonic radiation interference. The first of these problems was overcome with the development of Ultra High Frequency (UHF) DOPpler, or UDOP which operated at 450 MHz. An Offset UDOP was developed to overcome the second problem. Finally, a new system called Offset DOPpler (ODOP) was developed to maximise the effectiveness of the two previous systems. ODOP operated at 890 MHz [6, 24].

While the transplanted White Sands optical, mono-pulse radar, and Doppler radar tracking instruments were refined at the Eastern Test Range, the new facility created a third electromagnetic tracking device, phase-comparison radar. The first two phase-comparison radar systems were AZUSA and COrrelation Tracking And Ranging (COTAR) developed



KENNEDY SPACE CENTER showing the location of launch complexes, see tables pages 96-97.

Cape Canaveral Launch Facility Utilisation.

LAUNCH COMPLEX (Pad designation)	USE (Chronological Order of First Appearance)	CURRENT STATUS
Launch Area A*	Matador	No longer used.
Launch Area B*	Matador	No longer used.
Launch Area C*		No longer used.
Launch Area D*		No longer used.
1**	Snark Matador Heliport for Project Mercury Range Measurement Laboratory Balloon Release Area	Dismantled.
2**	Snark Matador Heliport for Project Mercury Range Measurement Laboratory Balloon Release Area	Dismantled.
3**	V-2/WAC-Corporal (Bumper) Bomarc Matador Hugo X-17 Polaris Medical Support for Project Mercury Spin Balance Facility for Thor/Delta Range Measurement Laboratory Balloon Release Area	Dismantled.
4**	Bomarc Redstone Jason Hugo Medical Support for Project Mercury Spin Balance Facility for Thor-Delta Range Measurement Laboratory Balloon Release Area	Dismantled.
5	Redstone (Including Mercury/Redstone) Jupiter Juno Space Museum	Inactive.
6	Jupiter Space Museum	Inactive.
7	-	Never built.
8	-	Never built.
9	Navaho Project Rise Now site of Launch Complexes 31 and 32	Dismantled in 1960.
10	Navaho Jason Now site of Launch Complexes 31 and 32	Dismantled in 1960.
11	Atlas	Salvaged in August, 1965.
12	Atlas Atlas-Able Atlas-Agena	Deactivated in December, 1967.
13	Atlas Atlas-Agena	Active.
14	Atlas (Including Mercury/Atlas) Atlas-Able Atlas-Agena Atlas-ATDA	Deactivated in February, 1967.
15	Titan 1 Titan 2 Blockhouse used by NASA KSC as Office Space	Sold for salvage in June, 1967.
16	Titan 1 Titan 2 Static Test Facility	Inactive.
17A	Thor Thor-Able Thor-Delta Thor-Able-Star	Active
17B	Thor Thor-Able-Star Thor-Delta Thor-ASSET	Active.
18A	Viking Vanguard Blue Scout Jr	Deactivated in February, 1967.

18B	Thor Blue Scout Scout	Deactivated in April, 1967.
19	Titan I Titan II (Including Gemini/Titan)	Deactivated in April, 1967.
20	Titan I Titan IIIA	Deactivated in April, 1967.
21 (Slant silo)	Bull Goose Mace	Deactivated.
22 (Slant silo)	Bull Goose Matador Mace	Inactive.
23	(Proposed Test Site for Ship Launched Version of Jupiter IRBM)	Never built.
24	(Proposed Test Site for Ship Launched Version of Jupiter IRBM)	Never built.
25A	Polaris	Dismantled.
25B (Ship simulator)	Polaris	Salvaged in September, 1969.
25C	Poseidon Trident	Active.
25D	Poseidon Trident	Active.
26A	Juno Jupiter Redstone Space Museum	Inactive.
26B	Jupiter Juno Space Museum	Inactive.
27	-	Never built.
28	-	Never built.
29A	Polaris Trident	Active.
29B (Ship simulator)	(Proposed Polaris Launcher)	Never built.
30A	Pershing	Dismantled in February, 1968.
30B	Pershing	Dismantled in February, 1968.
31A	Minuteman	Deactivated in September, 1969.
31B (Vertical silo)	Minuteman	Deactivated in September, 1969.
32A	Minuteman	Deactivated in December, 1970.
32B (Vertical silo)	Minuteman	Deactivated in December, 1970,
33	-	Never built.
34	Saturn I Saturn IB	Salvaged in April, 1972.
35	-	Never built.
36A	Atlas-Centaur	Active.
36B	Atlas-Centaur	Active.
37A	Built for Saturn I but never used	Salvaged in April, 1972.
37B	Saturn I Saturn IB	Salvaged in April, 1972.
38	(Proposed Dual Atlas/Centaur and Atlas/Agena capabilities)	Never built.
39A	Saturn V Space Shuttle	Active.
39B	Saturn V Saturn IB Space Shuttle	Active.
39C	(Proposed Saturn V Pad)	Never built.
39D	(Proposed Saturn V Pad)	Never built.
39DW	(Proposed Saturn V Pad)	Never built.
40	Titan IIIC	Active.
41	Titan IIIC Titan IIIE/Centaur	Active.
42	(Proposed Titan IIIC Pad)	Never built.

* *Launch Areas had no permanent facilities and were used for mobile testing. The Launch Areas were located on the tip of the Cape in front of Launch Complexes 1, 2, 3, and 4.*

** *Launch Complexes 1, 2, 3, and 4 were located near the marked location of the Ordnance and Cryogenic Test Building in front of Launch Complex 36.*

in the 1950's for use on the impending IRBM's and ICBM's. AZUSA was deployed in the launch area to obtain accurate long-range velocity and position information, while COTAR functioned at the other end of the ballistic missile flight at Antigua and Ascension to give equivalent data on the re-entry portion of the flight [34]. Both systems required a transponder on-board the missile in a manner similar to the two-way Doppler systems. On 5 December 1955 [29] the first missile equipped for AZUSA tracking, a Redstone, was launched from Cape Canaveral to test the new system in preparation for the Thor, Atlas, and Titan ballistic missiles. The system was operational the following year. The AZUSA was also the first launch site phase-comparison system used to provide impact prediction data for range safety. Phase-comparison systems at the Eastern Test Range after AZUSA, which had an accuracy of 30 parts-per-million, and COTAR, which had an accuracy of 25 parts-per-million, were the AZUSA Mark-II and later MISTRAM. AZUSA Mark-II replaced its namesake in 1961 with an accuracy of 17.4 parts-per-million. The MISTRAM system development began in 1959 as part of the Minuteman Program. MISTRAM had an accuracy of 3 parts-per-million [27, 6].

Telemetry expanded its capability exponentially at the Eastern Test Range. Approximately 60% of all data collected on a given missile was telemetry data. The 12 engineering events sensed on the Peenemünde V-2 telemetry system grew to 400 events by the time the Atlas ICBM was tested in the late 1950's, and when the Titan II began its testing programme at Cape Canaveral in 1961, a 2000 event system was used [27].

The AN/MPG-1 pulse radars used for impact detection at White Sands were replaced by sonic systems at the Eastern Test Range. The Missile Impact Location System (MILS) installed at Grand Turk, Antigua, and Ascension [27] consisted of six hydrophones located on the ocean floor in the vicinity of the intended impact point. MILS was useful for accurate flights, but the Broad Ocean Area (BOA) system was the impact detector on flights where the missile strayed from its desired trajectory. The older BOA system had hydrophones placed at 3,000 and 4,000 ft. depths over thousands of square miles of ocean area, but depended heavily on the missile carrying SOund Fuzing And Ranging (SOFAR) bombs for success. Both systems used LORAN-type triangulation to obtain results [6].

Ships and planes used this precise impact location to retrieve the ablative nose cones and model warheads on many ballistic missile shots. Such recoveries were first undertaken with the short-range Jupiter-C launchings in support of the Jupiter-IRBM Programme. The first Jupiter-C nose cone recovery took place on 8 August 1957 after a three hour search. The first full-size Atlas nose cone recovery occurred on 21 July 1959 [29].

Data processing involved such quantities of information that the IBM punched card machines were soon replaced by the descendants of the ENIAC electronic digital computer. The development of the FLorida Automatic Computer (FLAC) the first missile range developed digital computer, began in April 1951 and on 1 August 1953 FLAC went into operation. Both ENIAC and FLAC were first generation, vacuum-tube devices. FLAC was donated to George Washington University on 20 May 1959 after being replaced by the IBM-7090, a second generation, transistorised computer [24]. The present real-time data reduction is performed on two CDC-3600's and a CDC-3100, which are third generation, printed-circuit machines [28]. The real-time use of computers includes analysis of AZUSA-type impact prediction data, and the flying of aircraft and missiles to their targets using the Semi-Automatic Ground Environment (SAGE) system originally tested at the Eastern Test Range on the Bomarc missile.

Western Test Range*

In 1958, the vast array of range instrumentation developed at the Eastern Test Range was the foundation of a new ICBM range for operational testing to take the work load off the east coast facility. The new range was a slight variation on the original Point Mugu proposal of the Joint Research and Development Board. The launching facility was established on the California coast at Point Arguello, and the new range extended west-southwest across the Pacific Ocean to the Kwajalein and Eniwetok atolls. Instrumentation sites were located at various points along the California coast as well as on Hawaii and various other Pacific Islands. Instrumented planes and ships were used to fill the gaps and augment coverage in the impact area. Virtually every type of range instrument at the Eastern Test Range was used to outfit the new facility.

The main contribution of the Western Test Range to range instrumentation was in the area of impact detection. Having acquired the MILS and BOA systems from the Eastern Test Range, the new range developed the Splash Detection Radar (SDR) and the Broad Ocean Scoring System (BOSS) from the old White Sands AN/MPG-1 impact detection radar. SDR and BOSS were developed in conjunction with the Army Kwajalein Missile Range and were the primary impact location systems for operational ICBM testing in the 1960's. SDR operates like MILS to detect accurate impacts by identifying a minimum splash of 30 ft. amplitude and two second duration [36]. BOSS acts like BOA to give a general landing location for stray missiles.

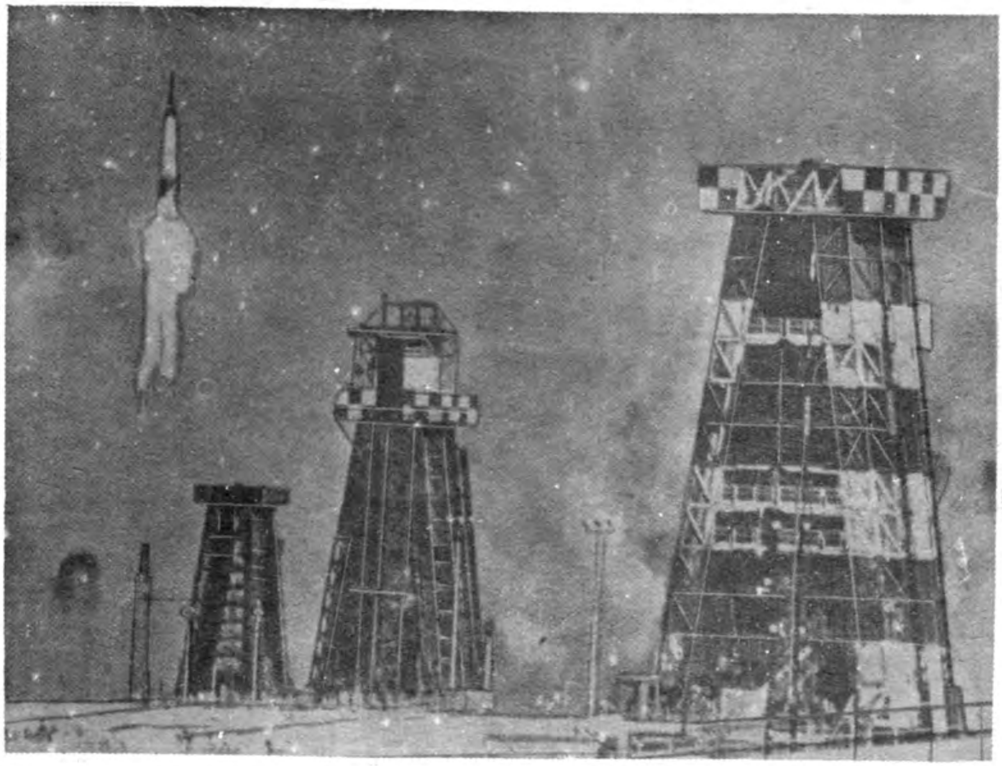
The Descendants and Spin-Offs

Range instrumentation was the basis for tracking in the space programme as well as in the early warning detection of missiles. Just as the Anti Ballistic Missile was being developed to neutralise IRBM's and ICBM's, the mono-pulse radar which contributed so heavily to their testing was developed in the Ballistic Missile Early Warning System (BMEWS) to give fore-warning of their offensive use, a long range equivalent to the airplane detection capability of the first mono-pulse radars in World War II. BMEWS also caused IBM to develop their first second generation computer, the 7090, later used at the Eastern Test Range [20]. The Doppler radar techniques were the basis for the satellite GLObal TRACKing (GLOTRACK) and DOPpler phase LOCk (DOPLOC) systems. MINITRACK, a NASA tracking system originally developed by the Naval Research Laboratory for the Vanguard satellite programme, capitalised on the angle-measuring phase-comparison systems like AZUSA and COTAR. A variation of MINITRACK called MICROLOCK

* *On 16 June 1958 the Pacific Missile Range was activated with headquarters at the old Naval Air Missile Test Center (NAMTC), later renamed Naval Missile Center, at Point Mugu, California. The new range included the Point Mugu range for short-range missile testing, an IRBM/ICBM and polar orbit insertion range with launch facilities at Vandenberg Air Force Base and adjacent Naval Missile Facility, Point Arguello, north of Point Mugu on the California coast, and an Anti-Ballistic Missile (ABM) range for the Army at Kwajalein Atoll. On 15 May 1964 shortly after the establishment of the National Range Division, the combined Pacific Missile Range was subdivided into three ranges. The short-range missile testing at Point Mugu retained the name Pacific Missile Range. The Army ABM testing facility was called the Kwajalein Test Site, a name it would retain until 15 April 1968 when it would receive its present title of Kwajalein Missile Range. The IRBM/ICBM and polar orbit insertion range was designated Western Test Range analogous to the Eastern Test Range [23, 25, 35].*

FIRST AMERICAN IN ORBIT. Major John Glenn starts his historic three orbits of the Earth from Cape Canaveral on 20 February 1962.

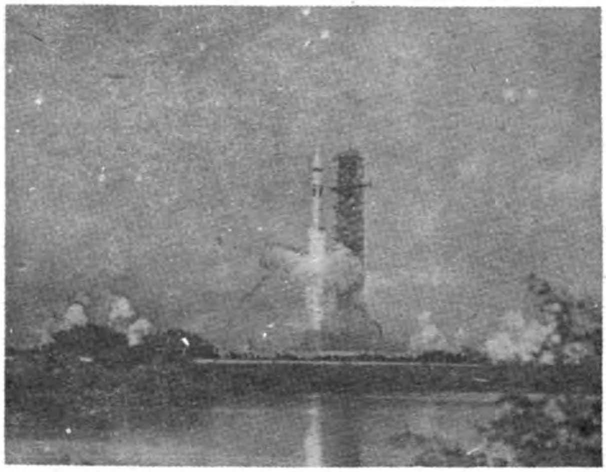
National Aeronautics & Space Administration



was developed for lunar and planetary distance tracking. Another descendant of MINITRACK was the Navy SPAce SURveillance (SPASUR) system. Even the optical tracking instrumentation of the missile ranges was converted to space programme usage; the Smithsonian Astrophysical Observatory operates Baker-Nunn 31 in. Schmidt-type telescopic cameras to track satellites.

With recoverable capsule-carrying reconnaissance satellites and manned flights, which use the retrieval techniques pioneered at the Eastern Test Range, comprising only 10% of all United States space launchings, the other most important range contribution to space research has been on-board instrumentation and telemetry. The United States orbited 32 capsule carrying reconnaissance satellites by 31 December 1973. During this same period 25 manned flights were made not counting the sub-orbital flights of Mercury/Redstone-3 and -4. This total of 57 was approximately 10% of the 558 total United States orbital launchings during the same period [37]. Obviously no satellite or spacecraft has ever flown without a telemetry system and for those hundreds of vehicles which are never deliberately returned to Earth, telemetry is their only means of providing useful information or receiving commands.

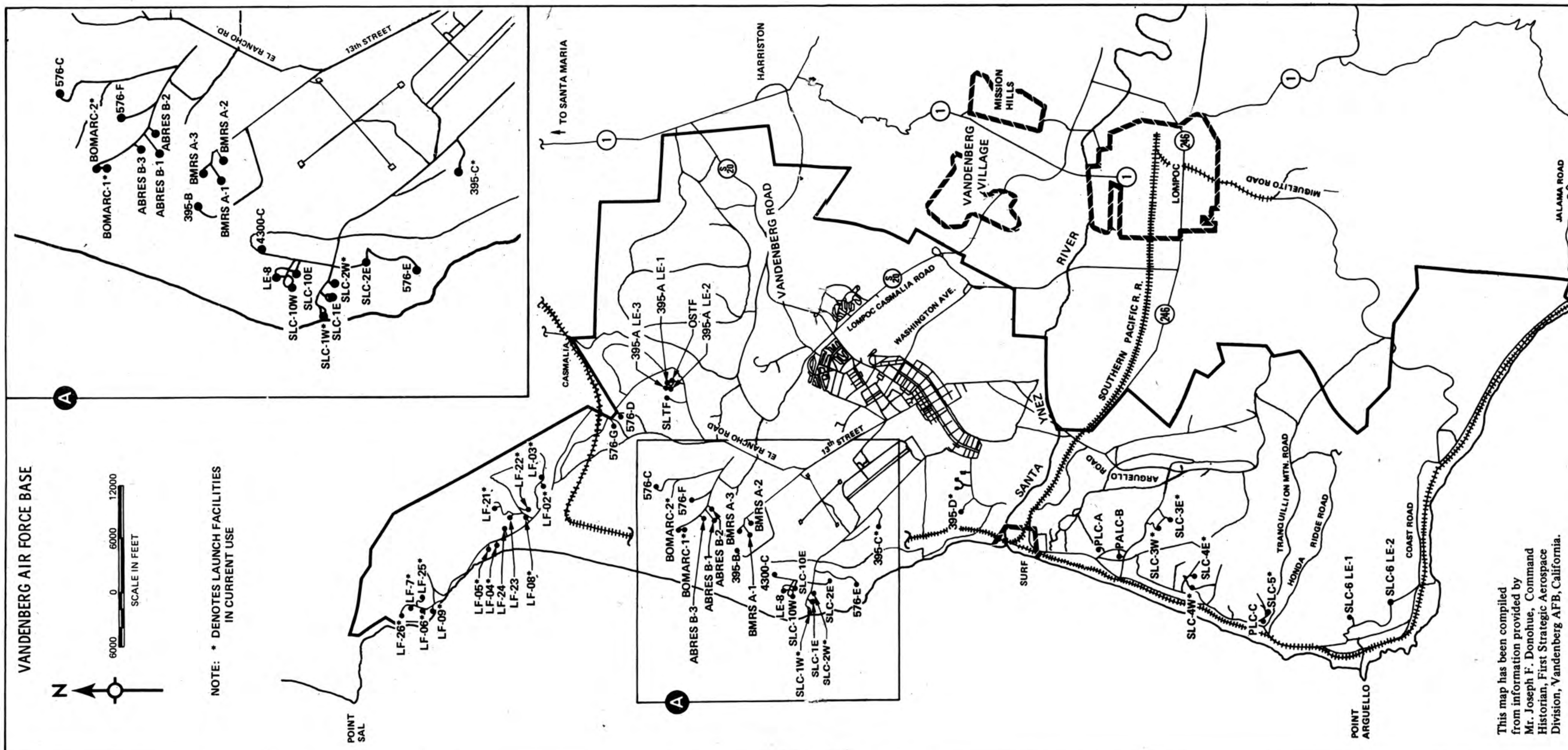
The tracking and telemetry techniques are combined to form the immediate descendant of the missile range, the tracking/telemetry network. The Space Tracking And Data Acquisition Network (STADAN) combines the MINITRACK, GLOTRACK, and DOPLOC systems and the Smithsonian Baker-Nunn cameras with a telemetry system to cover NASA Earth-orbital satellites. The descendants of MICROLOCK and the long-range telemetry techniques were combined to form the Deep Space Network (DSN) for NASA lunar and planetary flights. In fact, the California facility, one of the three primary DSN worldwide stations, is located at the site of the old Goldstone Range. The military equivalent to STADAN is the SPAce Detection And Tracking System (SPADATS) which combines telemetry with the tracking of Baker-Nunn cameras and radar systems like SPASUR. While the tracking capability of SPADATS, STADAN, BMEWS and all of the missile ranges combine to provide a general



SKYLAB 4. Third and last of three manned missions to the Skylab space station launched from the Kennedy Space Center on 16 November 1973. Aboard were astronauts Gerald P. Carr, Edward G. Gibson and William R. Pogue. Their mission lasted 2017 hours 15 minutes 32 seconds which stands as a world record to this day.

survey of all space vehicles for the North American Air Defense Command (NORAD), the telemetry capability of these networks provide the primary link in their testing and operational use.

The benefits of the United States missile ranges are not limited just to the missile and space efforts. The telemetry spin-offs include areas as diverse as stress-monitoring radio telemetry being used in the broken hips of orthopedic patients [38], and heat and pressure transducers being used to automatically control portions of factories. In the area of radar, distance-measuring phase-comparison techniques are used in extremely accurate satellite surveying systems



VANDENBERG AIR FORCE BASE showing the location of launch complexes, see tables pages 100-103.

Vandenberg Launch Facility Utilisation

LAUNCH COMPLEX (Pad Designation)	USE (Chronological Order)	PREVIOUS DESIGNATIONS	CURRENT STATUS
395-A LE-1 (Vertical silo with lift)	Titan I		Decommissioned and stripped.
395-A LE-2 (Vertical silo with lift)	Titan I		Decommissioned and stripped.
395-A LE-3 (Vertical silo with lift)	Titan I		Decommissioned and stripped.
395-B (Vertical silo)	Titan II		Decommissioned and stripped.
395-C (Vertical silo)	Titan II		Active.
395-D (Vertical silo)	Titan II		Active.
576-C (Coffin-type)	Atlas E		Decommissioned and stripped.
576-D (Vertical silo with lift)	Atlas F		Decommissioned and stripped.
576-E (Vertical silo with lift)	Atlas F		Decommissioned and stripped.
576-F (Coffin-type)	Atlas E Nike X	OSTF-1	Decommissioned and stripped.
576-G (Vertical silo with lift)	Atlas-F	OSTF-2	Decommissioned and stripped.

LAUNCH COMPLEX (Pad Designation)	USE (Chronological Order)	PREVIOUS DESIGNATIONS	CURRENT STATUS
4300 C	Scout Blue Scout Jr Scout/Scramjet		Decommissioned and stripped.
ABRES B-1 (Coffin type)	Atlas D Atlas/ABRES	576 B-1	Decommissioned and stripped.
ABRES B-2 (Coffin-type)	Atlas D Atlas/ABRES	576 B-2	Decommissioned and stripped.
ABRES B-3 (Coffin-type)	Atlas D	576 B-3	Decommissioned and stripped.
BMRS A-1	Atlas D Atlas-Burner-2 Atlas E Atlas F	576 A-1 4300 A-1 ABRES A-1	Decommissioned and stripped.
BMRS A-2	Atlas D	576 A-2	Decommissioned and stripped.

LAUNCH COMPLEX (Pad Designation)	USE (Chronological Order)	PREVIOUS DESIGNATIONS	CURRENT STATUS
BMRS A-2/contd.	Atlas/ABRES Atlas F	4300 A-2	
BMRS A-3	Atlas D Atlas E Atlas F	576 A-3 4300 A-3 ABRES A-3	Inactive.
BOMARC 1	Bomarc A Bomarc B		Active.
BOMARC 2	Bomarc A Bomarc B		Active.
LE-8	Thor	75-2-8	Decommissioned and stripped.
LF 00-02 (Vertical silo)	Minuteman II Minuteman III	394 A-1	Active
LF 00-03 (Vertical silo)	Minuteman I	394 A-2	Active.
LF 00-04 (Vertical silo)	Minuteman I Minuteman II Minuteman III	394 A-3	Active.
LF 00-05 (Vertical silo)	Minuteman I Minuteman II Minuteman III	394 A-4	Active.
LF 00-06 (Vertical silo)	Minuteman I	394 A-5	Active.
LF 00-07 (Vertical silo)	Minuteman I Minuteman II Minuteman III	394 A-6	Active.
LF 00-08 (Vertical silo)	Minuteman I Minuteman III	394 A-7	Active.
LF 00-09 (Vertical silo)	Minuteman I Minuteman III		Active.
LF 00-21 (Vertical silo)	Minuteman II Minuteman III		Active.
LF 00-22 (Vertical silo)	Minuteman II Minuteman III		Active.
LF 00-23 (Vertical silo)	Minuteman II Minuteman III		Decommissioned and stripped.
LF 00-24 (Vertical silo)	Minuteman II		Decommissioned and stripped.
LF 00-25 (Vertical silo)	Minuteman II		Active.
LF 00-26 (Vertical silo)	Minuteman II Minuteman III		Active.
OSTF (Vertical silo with lift)	Titan I		Destroyed in explosion 3 December 1960; deleted from real property records.
PALC-B	Kiva-Hopi		Decommissioned and stripped.
PLC-A	Blue Scout Nike-Javel in Super Loki Blue Scout Jr	PALC-A	Decommissioned and stripped.
PLC-C	Nike-Aerobee Paiute-Tomahawk Ute-Tomahawk	PALC-C	Inactive.
ALC-1E	Thor-Agena	75-3-5	Decommissioned and stripped.
SLC-1W	Thor Agena	75-3-4	Decommissioned and stripped.
SLC-2E	Thor Thor-Able-Star Thor-Agena Thor-Delta	75-1-1	Decommissioned and stripped.
SLC-2W	Thor Thor-Able-Star Thor-Agena Thor-Delta	75-1-2	Active.
SLC-3E	Atlas Atlas-Agena Atlas-SV-5D (PRIME) Atlas-Burner-2	PALC-1-2	Currently being modified.
SLC-3W*	Atlas-Agena Thor-Agena Thor-Burner-2 Atlas-Agena	PALC-1-1	Active.
SLC-4E	Atlas-Agena Titan IIID	PALC-2-4	Active.

United States Missile Ranges: Origin and History/contd.

LAUNCH COMPLEX (Pad Designation)	USE (Chronological Order)	PREVIOUS DESIGNATIONS	CURRENT STATUS
SLC-4W	Atlas-Agena Titan IIIB/Agena	PALC-2-3	Active.
SLC-5	Blue Scout Scout	PALC-D	Active.
SLC-6	Titan IIIM (Manned Orbiting Laboratory) Space Shuttle		Never completed; future construction for Space Shuttle conversion planned.
SLC-10E	Thor	75-2-7 LE-7	Inactive.
SLC-10W	Thor Thor-Agena Thor-Burner-1 (Altair) Thor-Burner-2 Thor-Burner-2A	75-2-6 4300 B-6 LE-6	Active.
SLTF (Vertical silo)	Titan I Titan II		Decommissioned and stripped.

* *SLC-3W was converted from Atlas/Agena facility to Thor-Agena and Thor-Burner-2 launch facility and then back to an Atlas-Agena launch facility.*

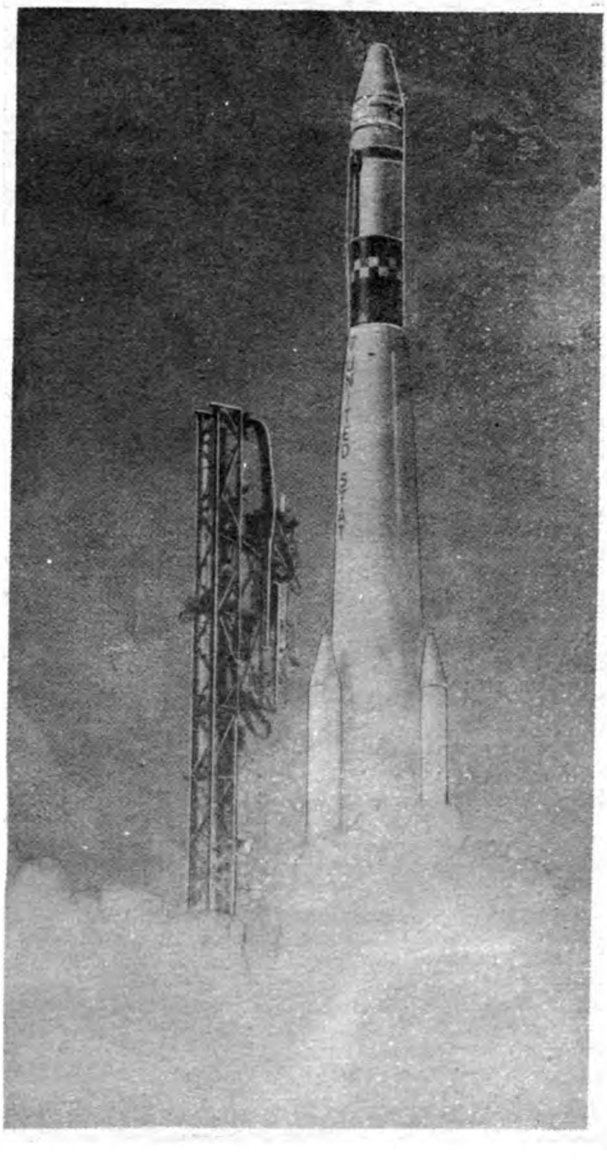
like Sequential Collation of Range (SECOR) and ELECTRO-TAPE [6], while Doppler systems are used to monitor the velocity of planes in flight to provide time-of-arrival predictions which parallel impact predictions made at the missile ranges [17].

The Future

According to John E. Naugle, the Associate Administrator of the National Aeronautics and Space Administration, ".... it may be better to conduct some of our industrial operations in space where there is abundant solar energy and an almost inexhaustible vacuum to act as a sink for thermal and chemical pollution" [39].

The future of American missile ranges will be greatly influenced by the new Space Shuttle, which will provide inexpensive transportation to and from Earth orbit, landing on a runway near its launch site like an aeroplane [40]. The Shuttle will soon dominate in the launching of space vehicles. In fact, the only launch vehicle presently scheduled to be used after the Space Shuttle becomes fully operational is the inexpensive Scout. The projected use of the Space Shuttle in space manufacturing, coupled with permanently orbiting space stations, may eventually transform the missile ranges into spaceports which handle passengers and cargo like their aeronautical counterparts. The declining missile range activity, as exemplified at the Eastern Test Range where the number of launchings dropped from a high of 201 in 1960 to a low of 20 in 1972, may be replaced by future growth away from their ballistic missile origins and building upon their space programme applications* [41].

* *With the coming of the Space Shuttle, the USAF contemplates closure of the Eastern Test Range in the mid-1980's. By that time the last of the expendable launch vehicles, probably the Titan 3C, will be retired from the ETR and only the Navy Trident development would remain. Shuttle operations at the Kennedy Space Center will not require downrange instrumentation "once the vehicle becomes fully operational in conjunction with the tracking and data relay satellite system."*



Right, a Thrust-Augmented Thor-Agena D blasts off from the Western Test Range, California, with the inflatable 100 ft. (30.5 m) Pageos 'balloon' satellite on 24 June 1966.

United States Missile Ranges: Origin and History/contd.

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MILESTONES *Continued from page 82]*

changes are caused in elementary living cultures by exposure to space radiation. Samples attached to the outside of the spacecraft will be compared with control samples inside the station.

10 Soviets launch Soyuz 27 from Tyuratam at 15.26 hr. (Moscow time) into orbit of 257 x 302 km inclined at 51.6 deg to equator; period 89.9 min. Cosmonauts are Lt-Col. Dzanibekov and flight engineer Oleg Makarov.

11 Soyuz 27 docks with Salyut 6 at 17 hr. 6 min. (Moscow time) using docking unit on transfer module used unsuccessfully by Soyuz 25 in October 1977. (On-board crew retreated to Soyuz 26 during the docking so they could break away in case of an emergency). Three hours later Dzanibekov and Makarov emerged into station to be welcomed by Romanenko and Grechko who received fresh food, mail and other cargo. They are scheduled to stay five days before returning in Soyuz 26 ferry.

12 Orbit of Soyuz 26/Salyut 6/Soyuz 27 combination is 334 x 367 km x 51.6 deg; period 91.3 min.

BAC AND THE SPACE TELESCOPE

The Space Telescope, to be carried into orbit by the Space Shuttle in 1983, is the World's most ambitious space astronomy project. The 2.4 metre (94 in.) aperture instrument is expected to dominate astronomical research for the rest of the century by opening up new fields of research at present unattainable and impossible to duplicate on Earth. It will enable scientists to study stars and galaxies 20 thousand million light years from the Earth. Its precision optical system, operating in the space environment and capable of pointing anywhere in the celestial sphere, will resolve stellar detail ten times smaller than any Earth-based system. Functional in the ultraviolet, visible and infrared wavelength regions, it will observe objects 50 times fainter than possible from the ground. The space telescope will be an international facility, operated in a manner similar to ground-based observatories, and accessible to astronomers throughout the world.

Astronomical advisory groups have studied the use of such a space telescope since 1965 and have identified a number of key areas of study including the measurement of the rate of expansion of the Universe; investigation of the structure of galaxies; exploration of the nature of quasars, neutron stars and X-ray sources, and detailed studies of planets.

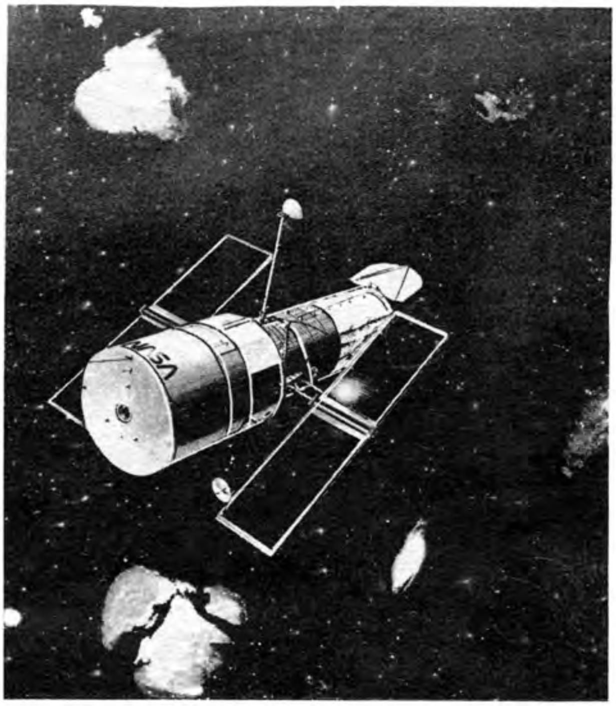
The Space Shuttle provides the capability to place not only the Space Telescope in orbit, but also to conduct repair/maintenance activities in orbit and return the system to Earth for refurbishment and updating. In this way, the instrument will remain technically current and at the forefront of international astronomical science.

It is, therefore, with great satisfaction that we record the receipt by British Aircraft Corporation, Electronic and Space Systems of two major contracts totalling £13.3 million to support this important American project.

The contracts, awarded by the European Space Agency, will run for five years and four years respectively. The first, valued at £6 million, covers the development and manufacture of the Space Telescope Solar Array that will power the telescope during its 10-15 years lifetime in space. The second contract for £7.3 million is for the development and manufacture of a Photon Detector Assembly (PDA) which is the heart of a 'faint object' camera, one of five focal plane space telescopes. For this contract, BAC will lead a consortium of 11 companies from eight European countries and, in addition to the management and system engineering of the PDA project, will also be responsible for the pattern recognition electronics.

Lockheed Missiles and Space Company of the United States are the main contractor to NASA for the telescope's structure and support systems and Perkin Elmer Corporation will build the optical telescope assembly at their optical division in Danbury, Connecticut. Under the terms of a NASA-ESA agreement approximately 15 per cent of the project will be developed in Europe. In return, European astronomers will be allocated not less than 15 per cent of the total observing time.

The Space Telescope is housed in a cylinder 14.3 m long and 4.7 m in diameter. It comprises the 2.4 m primary mirror, and four scientific instruments, including a camera located in the focal plane of the telescope and a faint-object camera. It will be placed into near Earth orbit at a nominal altitude of 500 km (311 miles) where, above the optically obscuring effects of the Earth's atmosphere (haze, twinkling and light absorption), it will be capable of detecting objects 50 times fainter and seven times further away than can be seen with telescopes on Earth. These improvements open up to observation an immense new volume of space. The telescope will be able to separate objects less than a tenth of a second of arc apart and to observe remote celestial objects nearly 100 times fainter than those observable from the ground. In addition to the visible region of the spectrum, it will give access to the ultraviolet region in the range from 1,000 to 3,000 Angstroms, which is unobservable from the ground, and to the infrared region. It will thus be possible to observe celestial objects as they were at the very formation of the Universe, a time which some theories place between 12,000 and 20,000 million years ago.



The NASA Space Telescope to be launched by astronauts from the Space Shuttle in 1983.

British Aircraft Corporation

Fully extended the Telescope's solar array will comprise two identical deployable and retractable solar panels employing a double roll-out flexible substrate upon which the solar cells will be mounted. Fully extended the array will occupy an area of about 33 m^2 (356 ft^2) and after two years in orbit it should still be able to supply over 4,000 watts of electrical energy.

The Space Telescope must be able to be both maintained in space and retrieved by the Space Shuttle for more extensive refurbishment on Earth; consequently the array must be retractable. This is the first time in Europe that such a feature has had to be considered in the design of spacecraft power supplies. With the advent of Space Shuttle, however, and the advantages of long life re-usable systems, this vital feature will become more commonplace in future space enterprise.

A Faint Object Camera will be used to detect and record images of celestial objects so faint that the pictures are to be built up by counting the individual photons of light arriving one after the other at the focal plane of the tele-

scope. The camera will focus these photons on to the Photon Detector Assembly (PDA), which will amplify the light of individual photons until their position can be recorded by a low light level television camera tube. The signal from the camera tube will be analysed by a complex electronic pattern recognition logic unit to build up the image of the star.

The BAC consortium for development of the Photon Detector Assembly comprises: Ad Tec (Ireland); Contraves AG (Switzerland); CGE-FIAR (Italy); Dornier System GmbH (Germany); Elektronikcentralen (Denmark); EMI (UK); ETCA SA (Belgium); Science Research Council (Appleton Laboratory) (UK); Technisch Physiche Dienst TNO-TH (Holland), and University of Liege (Belgium).

SHUTTLE AT VANDENBERG

Ever since the $1.5 billion dollar Manned Orbiting Laboratory (MOL) Program was cancelled in 1969 the extensive launch complex constructed for it at the Vandenberg Air Force Base, California, has kept a lonely but hopeful vigil. Its long and patient wait is to be rewarded.

In the 1980's, it is now planned by the US Air Force to use this facility along with others to launch, land and refurbish NASA's exciting new Space Shuttle.

NASA will routinely use shuttle orbital flights as a platform for deploying satellites and laboratories in space, for servicing near Earth-orbiting space vehicles, and as a launch pad for satellites and spacecraft destined for higher orbital latitudes as well as interplanetary probes.

After the Orbiter lands at Vandenberg, special inspection and refurbishing for flight will be carried out in a large hanger-like building called the Orbiter Maintenance Checkout Facility. After checkout, the Orbiter will be moved to Vandenberg's Space Launch Complex number six (nicknamed SLC-6), where it will be mated to its external fuel tank and two additional solid-rocket boosters.

The external fuel tank will then be loaded with liquid oxygen and liquid hydrogen, and a flight crew of up to four astronauts will enter the Orbiter cockpit.

The Space Shuttle, because of its size and power, represents an exercise in advanced support concepts and logistics. For instance, the solid rocket booster 'SRB' segments will be shipped to VAFB by the Southern Pacific railroad. When assembled, these SRB's will stand one hundred and fifty feet high and be well over twelve feet in diameter, with a launch weight of over one and a quarter million pounds each.

The next step in the Orbiter launch assembly will be the mating of a large lox-hydrogen fuel tank to the SRB's. The lox-hydrogen fuel tank is expected to be transported to the Vandenberg area *via* oceangoing barge. This form of transport is necessary because the fuel tank, as large as the body of a commercial DC-10 airplane, is too bulky for any other means of transport.

After delivery to VAFB, the external tank will be towed over existing base roads to the launch pad complex at SLC-6. Assembling the entire launch vehicle there saves the cost of building a new assembly structure similar to the vertical assembly building at Kennedy Space Center, Florida. Finally, the Space Shuttle Orbiter, as large as a commercial DC-9 airplane, will be mated to the fuel tank. When fuelled, the Orbiter and its booster assembly will weigh over four million pounds.

EUROPEAN COMMUNICATIONS SATELLITE

An initial release of funds totalling £3.74 million for the full development of the initial ECS (European Communications Satellite) has been made by the European Space Agency (ESA) to Hawker Siddeley Dynamics who will lead the MESH consortium of European companies in this important programme. The full development contract will be worth approximately £34.5 million.

ECS will be a fully operational European regional satellite communications system and will be capable of carrying a significant proportion of future European telephone, telex and TV traffic. The first ECS will be placed in geo-stationary orbit in 1981 by the European Ariane launcher and it is planned that this should be followed by three more between then and 1990. The launches will be made from the equatorial site at Kourou in French Guiana.

ECS will be based on the technology of the European Space Agency's Orbital Test Satellite, also built by the MESH consortium. Following the loss of the first OTS flight model as a result of the failure of the Delta 3914 launch vehicle, a reserve spacecraft, which was planned into the programme to meet such an eventuality or to be used for an extension to the Marots programme, is being prepared to meet a launch date during the first half of 1978.

MUTED 'BIG BANG'

Was the Big Bang explosion that marked the beginning of the Universe violent and chaotic? Many scientists think so, but recent measurements by a team of researchers using a high flying NASA aircraft suggest that the Cosmos may have started more serenely – with a powerful but tightly controlled and completely uniform expansion.

Using ultrasensitive radio equipment aboard an Ames Research Center U-2 jet, the research team measured the cosmic microwave background – the radiation left over from the Big Bang, the initial, Universe-forming event – and concluded that this initial event was a very smooth, almost serene process, with matter and energy uniformly distributed and expanding at an equal rate in all directions. The findings were made by Drs. Richard Muller, George Smoot and graduate student Marc Gorenstein of the Lawrence Berkeley Laboratory and the University of California at Berkeley, who also designed and operated the radio equipment.

The researchers also found that the Milky Way Galaxy, together with the Solar System and Earth, appear to be racing through space at more than one million miles per hour towards the constellation Hydra.

"The radiation left over from the Universe-forming event about 15 thousand million years ago is so uniform that it provides a universal reference for measuring this motion," says Gorenstein. Another major surprise is that the U-2 measurements seem to show that there is no rotation of the Universe. "This is surprising because we can see that everything within the Universe is rotating – planets, stars, and galaxies", says Smoot. "If there is rotation, it has to be less than one hundred millionth of a rotation in the last thousand million years."

"Our measurements give a picture of an extremely smooth process," declare the researchers. "The 'Big Bang', the most cataclysmic event we can imagine, on closer inspection appears finely orchestrated. Either conditions before the beginning were very regular, or processes we don't yet know about worked to make the Universe extremely uniform." The uniformity was greater than one part in 1,000 for matter, one part in 3,000 for energy, and one part in 10,000 for expansion.

According to the currently accepted "Big Bang" theory, the Universe began as a hot, incredibly dense mass containing all the matter in the Universe. At a certain "initial" instant, the primeval fireball exploded in the vastest cataclysm imaginable.

As the Universe continued its expansion and the tempera-

ture dropped, protons and neutrons began to fuse into nuclei and remained fused for increasing longer periods of time. They formed first hydrogen, then deuterium and later helium. After millions of years, the material had cooled sufficiently to condense into galaxies and within the galaxies into stars and planets. As a consequence of the colossal explosion, the galaxies have continued to separate from each other, and thus form the expanding Universe we observe. Those galaxies farthest from Earth appear to be travelling the fastest.

"The large scale regularity we have found in the expansion of the Universe makes the million-mile-an-hour random local motion we have detected for the Earth and our Galaxy all the more surprising," Smoot says.

The U-2 aircraft, at an altitude of 19,800 metres (65,000 feet), flies above 90 per cent of the Earth's atmosphere where these sensitive experiments must be conducted. When it is not investigating the Cosmos, the U-2 is used for agricultural and Earth resources photography.

The project was funded by the Department of Energy and NASA. Measurements so far have covered almost the entire sky over the northern hemisphere, half the celestial sphere.

NASA SETI PROJECT

Following our exclusive report of NASA interest in the search for extra-terrestial intelligence (*Spaceflight,* October 1976, p. 343) the Jet Propulsion Laboratory in Pasadena, California, has announced the go-ahead for a five-year programme to survey 80 per cent of the sky, "searching for evidence of radio signals from intelligent extra-terrestrial life."

The JPL statement reads: "The project is a modest, beginning approach to one of the most profound questions mankind has ever asked: 'Are we alone in the Universe?'

"Project SETI will use two antennae, and advanced microcircuitry and data-processing techniques to survey the sky simultaneously across one million frequencies. The five-year survey is to begin in October 1978, after a two-year implementation period.

"Radio signals come to us from nearly every quarter of space, all apparently of natural origin. The objective of the SETI project will be to sort out and reject those natural signals and man-made radio-frequency interference, and to identify possible artificial signals from a source somewhere in the Milky Way galaxy".

NAVAJO SPACE SCAN

The Navajo nation is preparing to apply space technology using a NASA Earth resources satellite to assist them in managing natural resources on the 16 million acre Navajo reservation in the southwestern United States.

Emphasis will be placed on high-priority activities that are geared to multiple use management, specifically range rehabilitation, timber, agriculture, harvest prediction and wildlife inventory.

The Navajos contacted NASA to investigate the use of satellite and aerial remote sensing techniques for specific applications to Navajo resource inventory and management problems. The project will be conducted in two phases:

- Phase one will demonstrate the utility of Landsat data to specific Navajo needs and applications and the ability of Landsat data to update resources changes.

- Phase two will be essentially a transfer of technology and will include comprehensive training of Navajo personnel and the setting up of an operational system at Navajo Nation Headquarters, Window Rock. This phase will also include Navajos actively participating in assisting other Indian tribes in realising the benefits of satellite information systems.

Landsat, circling the globe 14 times a day 912 km (560 miles) overhead, surveys Earth natural resources with an electronic multispectral scanner that returns data for visual images and computer tapes from which experts can distinguish different types of terrain, vegetation, soils, rock outcrops and other surface features.

Besides mapping forests and possible mineral areas, the data has been used for measuring crop acreages, mapping snow cover, detecting oil slicks, mapping urban and agricultural land use, detecting offshore dumping of sewage and industrial waste, monitoring the environmental effects of strip mining and locating potential earthquake zones.

"HOMEMADE" ORBITER

Before the real Space Shuttle Orbiter arrives in Alabama this month, a "homemade" Orbiter made from rocket scrap parts and steel beams has been nosing along the streets of NASA's Marshall Space Flight Center and standing in for the real Orbiter during practice lifts into the tower where the Orbiter will soon be tested.

The real Orbiter, the plane-like, manned portion of the Space Shuttle, last year successfully completed the series of landing tests in California held to prove it could perform the approach and landing portion of the Shuttle's mission profile.

The next series of tests, at Marshall, will check out the ability of the Orbiter and the other components of the Space Shuttle to maintain proper guidance and control under vibration conditions encountered during launch and powered flight.

Before the real Orbiter arrives, Marshall Center engineers are using the simulated Orbiter to practice many of the tasks they know will have to be done right on the first try with the real thing.

The simulator first was used to try out the facility that removed Enterprise from her 747 carrier aircraft. It was towed along the roadways the Enterprise will follow, testing clearances on all sides.

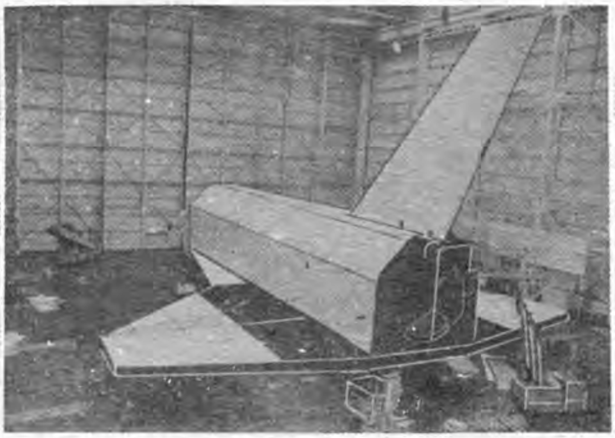
But the most dramatic use comes when engineers at Marshall practice hoisting it into the 131-metre (430 ft.)-tall test stand where the Enterprise will be mated to the other Space Shuttle components for the first time.

The simulator's size, shape, weight, and centre of gravity closely match that of Enterprise; so does its wind resistance. The engineers, therefore, will get a real taste of things to come when the simulator is delicately hoisted into position, then gingerly lowered down inside the stand.

Werner H. Rubel, a supervisor in the product planning branch, fabrication division of the Test Laboratory, said that the idea and design for the "dummy" Orbiter came out of his division, which is also doing the assembly. A scrapped Titan solid rocket motor case, 3.04 metres (10 ft.) in diameter and 24.39 metres (80 ft.) long, forms the nucleus of the simulator. The Titan case was used at Marshall most recently for simulator work in Space Shuttle solid rocket booster structural tests.

"We have added frames, collars, nose, and tail structures, and wings," Rubel said, "and we finished with aluminium sheeting for the outer skin."

The outer skin was necessary to determine the effects of wind when the vehicle is lifted into the huge, vertical stand, he explained.



A simulated Space Shuttle Orbiter takes shape in an assembly area at NASA's Marshall Space Flight Center, Huntsville, Alabama. The simulator's size, shape, weight and centre of gravity closely match that of the real Orbiter Enterprise, which is due to arrive in Alabama in March. This "homemade" Orbiter is being used to try out the facility that will remove Enterprise from its carrier aircraft, test roadway clearances, and practice installation into the tall test tower where the ground test programme will take place.

National Aeronautics and Space Administration

The Orbiter simulator is 37.5 metres (123 ft.) long and has a 23.78 metre (78 ft.) wingspan. This compares closely to the real Orbiter which is 37.24 metres (122.2 ft.) long with a 23.79-metre (78.06 ft.) wingspan. The simulator will weigh about 200,000 lb. which compares to the real Orbiter which weighs about 192,000 lb.

When the "homemade" Orbiter completes its work at the Marshall Center, it will be shipped by barge to the Kennedy Space Center, Florida, where engineers will check out procedures for launch preparations. It has also been requested for use at Vandenberg Air Force Base in California, where the Department of Defense is preparing Shuttle launch facilities.

U.S. ASTRONAUT STATUS

A recent NASA news release gives details of the current status of the 73 pilots and scientists selected as astronauts since April, 1959, writes Robert D. Christy. Twenty seven of them are still available for flights, 17 as pilots and 10 as scientists. One of the pilots, William Pogue of Skylab 4 is on leave of absence.

Of the original 1959 group of Mercury astronauts only Donald Slayton is still on flight status. Slayton will be remembered as having to wait until the Apollo-Soyuz Test Project in 1975 before getting his first flight. His opportunity of a Mercury flight was lost when a heart problem was detected. He is presently the Manager for Approach and Landing Tests in the Space Shuttle Program Office at the Johnson Space Center. Virgil Grissom was killed in the AS201 fire at the Kennedy Space Center in 1967, John Glenn is a US senator and the other four have retired into private business or industry.

A group of test pilots was selected in 1962 and a further group of pilots in 1963. These two groups provided most of the Gemini crews of 1965-66. Only John Young (Geminis 3 and 10, Apollos 10 and 16) and Alan Bean (Apollo 12 and Skylab 3) are still active. Training accidents took their toll from these two groups with four of their number being killed flying T-38 jet aircraft. Roger Chaffee and Ed White (the first American to walk in space) died in the 1967 launch pad accident.

Of a 1965 group of six scientists, two resigned before making a flight, Harrison Schmitt was the Lunar Module pilot on Apollo 17; Joseph Kerwin, Owen Garriott and Edward Gibson flew as science pilots on the three Skylab missions.

Eight out of a group of 19 pilots selected in 1966 are on flight status; the number includes Vance Brand, the ASTP command module pilot and Fred Haise the lunar module pilot of Apollo 13. William Pogue is on temporary leave of absence.

The first all-civilian group of eleven men was formed in 1967 but as yet none have flown and only five are still active.

With the cancellation of the USAF Manned Orbiting Laboratory, seven pilots were transferred to NASA during 1969. Charles Fullerton and Richard Truly headed the Shuttle Approach and Landing Test crews during 1977. Fullerton made both the first captive and free flights of the vehicle along with Fred Haise of the 1966 group.

SOVIET SPACE EXHIBITS

At the Soviet Exhibition of Economic Achievement in Moscow one can inspect a realistic replica of the Salyut 4 space station and much of its internal equipment. A similar vehicle was brought to the Paris Air Show last year as part of an impressive Soviet space exhibition commemorating the 20th anniversary of Sputnik 1.

At these impressive displays, writes Robert D. Christy, one could climb the stairs through the aperture in the station left by removing the conical housing of the solar telescope.

In spite of its length of about 14 metres and up to 3 metres diameter, Salyut is not the roomiest of craft and one would not exactly relish spending two months aboard with a single companion, let alone with the two originally envisaged by its designers.

One is immediately struck by the internal colour scheme. Soviet descriptions state that one half of the station is painted a light colour and the other a dark one to give the sense of 'up' and 'down' in the weightless condition. The replicas confirm this although the layout of the colour scheme is such that the major work stations are located on the artificially created 'walls' and are laid out in such a way that they are operated with the cosmonaut at right angles to the local 'vertical'.

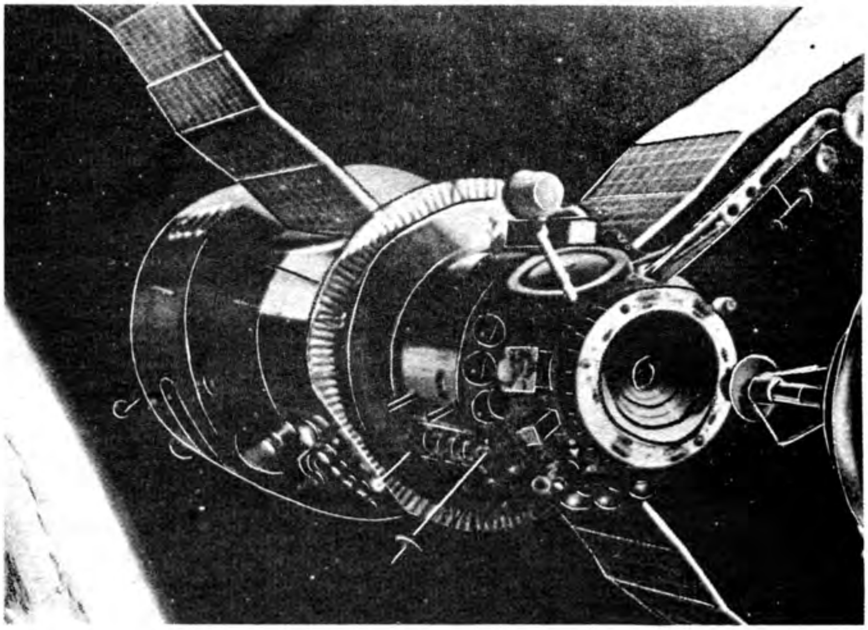
Other features of the station are seen in the photographs by Theo Pirard and H. P. Griffiths which appeared in last month's issue. They show the 19 tonne vehicle in its Salyut 4 configuration, with the three large solar panels and some of the internal equipment. The 250 mm solar telescope is the subject of a separate exhibit.

THE IMPROVED SALYUT

The addition of a second docking port in Salyut 6 has not greatly affected the weight or overall dimensions of the basic space laboratory. The modification to the instrument compartment has, however, involved the re-positioning of engine components at the back of the station to permit the installation of the docking port on the axis, writes Kenneth Gatland.

Salyut 6 has two docking ports, one at each end. Illustration shows the docking port on the transfer compartment with which Soyuz 25 failed to dock in October. Soyuz 26 used the new docking port on the instrument section (obscured in this view). Following an EVA inspection of the forward docking unit on 20 December by the Soyuz 26 cosmonauts, Soyuz 27 made a successful link-up on 11 January which allowed Vladimir Dzanibekov and Oleg Makarov to join Yuri Romanenko and Georgi Grechko aboard the station.

Photo of a Soviet painting by Theo Pirard



According to Dr. Konstantin Feoktistov, the leading designer of Soviet spacecraft who is also a cosmonaut, the presence of two docking ports "gives a bigger safety margin, especially in docking operations, and opens up the possibility of a station working simultaneously with two transport ships, including the delivery of extra scientific equipment and foodstuffs."

Preparations for the EVA took the following sequence. Both cosmonauts entered the transfer compartment and donned a new type of semi-rigid, full-pressure suit. After checking the life support system, they closed the hatch between the working and transfer compartments and depressurised the latter.

With Romanenko controlling the EVA from within the transfer compartment, the hatch was opened at 00.36 hr. (Moscow time) and Georgi Grechko began his walk. He checked the area around the transfer compartment and docking unit for possible damage and inspected the joints, sensors, guide pins, fasteners and seals. The inspection, which included use of special assembly, control and adjusting tools, was carried out on illuminated and shadow portions of the orbit and using a handheld TV camera Grechko was able to transmit to Earth pictures of the docking unit and other parts of the station. However, there was no evidence of any damage which would have prevented a successful docking and presumably suspicion now rests with the docking unit of Soyuz 25 which, of course, was lost with the discarded orbital module during the re-entry sequence.

During the EVA the cosmonauts also took the opportunity to check "methods and new conceptions" of making an exit into space. Stable radio contact was maintained with the cosmonauts throughout the operation.

After completing the walk and closing the outer hatch, the cosmonauts brought the transfer compartment back to normal pressure, removed their suits, opened the internal hatch and returned to the main compartment. The total operation lasted 1 hr. 28 min.

It remains to be seen if unmanned spacecraft will be used for supply operations, as envisaged during the Soyuz 20 mission to Salyut 4, and if additional air and fuel supplies can be carried up to Salyut stations to keep them in orbit for much longer periods.

Commenting on the latest modifications, Feokistov points out that all the main units of Salyut 6 are controlled from the same console and thanks to an economical system of orientation and steering, the crew are relieved of many navigating chores. One of the cosmonauts' first duties was to check their Delta autonomous navigational system in conjunction with ground stations.

Water regeneration from condensate is now standard aboard Salyut and the cosmonauts receive information from Mission Control on a portable teleprinter.

TV cameras aboard the station have also been improved. Salyut 6 has no fewer than six, one colour and two black and white inside and three black and white outside. The cameras are similar to those flown on Soyuz 19 during the Apollo-Soyuz Test Project in 1975.

Scientific equipment aboard the station has also been improved as the result of past experience. "especially equipment for astrophysical experiments and for the monitoring of Earth resources."

All this has been done, Feoktistov says, without denying the crew amenities with which they have already become accustomed. Salyut 6 retains the full range of physical exercising apparatus and the station even has a collapsable shower closet with a hot water spray. A suction device is provided for mopping up!

On the future of space station activities, Feoktistov says there are prospects for the manufacture of semi-conductors, crystals, medicines and other substances with unique properties. Not only factories but power stations might be established which transform solar radiation into electric power transmitted to Earth.

Vast fields of photoelectric cells in geo-stationary orbit extending for tens of kilometres, or mirror solar concentrators focussing beams on steam turbo-generators, would hover permanently above the same part of the Earth. The parts, assembled in low Earth-orbit, would be propelled into final position by tugs.

1980 BIO-SATELLITE

The Soviet Academy of Sciences have invited NASA to participate in another bio-satellite mission to be carried out in the first quarter of 1980. Space officials anticipate that the vehicle will again be a Vostok type similar to the

previously-launched Cosmos 605, 690, 732 and 936.

One Russian proposal is to fly two to four primates to extend research previously made with rats aboard Cosmos 936 last year. (*Spaceflight*, October 1977, p. 366). On that mission, which lasted 18.5 days, two sets of rats were carried, one in cages mounted on a centrifuge to provide artificial gravity and the other in zero-gravity conditions. A third set of rats remained on Earth as a control sample.

X-RAY SPACE OBSERVATORY

A proposed Earth-orbiting observatory known as the Advanced X-ray Astrophysics Facility (AXAF) was the subject of a first meeting of a Science Working Group held recently as NASA Headquarters, Washington, D. C. Under the chairmanship of Professor R. Giacconi of Harvard University, the Committee has the task of formulating scientific requirements for the AXAF in support of a study of the system by NASA's Marshall Space Flight Center. Members of the Committee are drawn from universities and government laboratories involved in the field of X-ray astronomy and include European X-ray astronomers.

The scientific objectives of the AXAF mission would include studies of stellar structure and evolution, large-scale galactic phenomena, the nature of active galaxies, rich clusters of galaxies and cosmology.

The long-lived X-ray observatory, proposed for launch by the Space Shuttle in the mid-1980's, would be capable of being repaired or retrieved in orbit through use of the Shuttle. The satellite would be approximately 12.8 metres (42 ft.) in length and weigh about 9,000 kg (20,000 lb.).

According to Dr. Martin C. Weisskopf, the AXAF study scientist at the Marshall Center and vice-chairman of the Science Working Group: "The discoveries of the past few years have clearly established that X-ray astronomical observations are an essential tool in the study of many of the objects of greatest current astrophysical interest, such as pulsars, quasars, clusters of galaxies, and the intergalactic medium. The study of compact X-ray emitting objects in binary systems, white dwarfs, neutron stars and possibly 'black holes' permits investigation of the properties of stars near the end of their lives and of the physics of matter at extreme pressure, densities, and magnetic fields. Thus, studies of this type have bearing not only on questions of astrophysical interest, but impact work on energy-related problems here on Earth."

With the AXAF, X-ray observations can be extended greatly, Weisskopf said. "It will be possible to detect and resolve clusters of X-ray emitting galaxies at the extreme reaches of the Universe and study their evolution over times comparable to the age of the Universe."

SPACE AID TO MINING

Technology that allowed men to explore the Moon may make coal mining safer, more productive and more economical.

Using technology developed for the Lunar Roving Vehicle that was operated so successfully on the Moon, an automated guidance and control system is being applied to a coal mining machine by engineers at the Marshall Space Flight Center in a project for the Department of the Interior's Bureau of Mines.

The "longwall machine," now operated by miners, is a large shearing machine that grinds coal from a wall or face of a coal seam in a more or less straight line, sending coal out on a conveyor, and advancing together with its mechanized roof supports as it travels deeper into the seam.

Automating this machine would bring enormous advantages and would eliminate the need for a human to work next to the cutting operation, often an unhealthy and unsafe environment.

EVOLUTION OF THE SPACE SHUTTLE

Text and drawings by David Baker

8. EXTERNAL TANK DESIGN – 2

[Continued from February issue, page 66.

Propulsion System

Elements described in this subsection will include the propellant management, pressurisation, vent/relief and tumbling subsystem hardware. The LO_2 feedline assembly carries propellant from the forward mounted LO_2 Tank through a cut-out in the Intertank and down the outside of the LH_2 Tank along a line displaced 23° from the top ET centreline to a 90° turn immediately below the right aft umbilical disconnect plate from where it is delivered to the Orbiter.

The feedline starts at the LO_2 inlet/outlet fitting (and located on the exterior of the dome section end-cap offset 8° from the tank centreline). The forward flexible assembly is flange-mounted to the LO_2 inlet/outlet fitting by 44 0.8 cm bolts at one end and turns through an angle sufficient to bring the other end close to the Intertank skin panel. A flexible elbow pipe is flange-bolted to the forward flexible assembly by 44 1.1 cm bolts which bring it through an Intertank skin panel where it turns through an angle sufficien to bring it down the side of the ET a distance of about 274 cm.

At this point it is attached to four straight pipe sections totalling 21.41 m in length which carry liquid oxygen down the side of the LH_2 Tank. The forward straight pipe section is 629 cm long, the middle two sections are each 626 cm long and the aft section is 260 cm long. The rear of this section is attached to a 194.6 cm long aft flexible assembly which in turn is attached to a 90° aft elbow and all pipe sections from the forward flexible elbow are connected together with 36 0.9 cm bolts at each interface. The 90° aft elbow is secured to the right aft umbilical disconnect plate by 48 0.8 cm bolts.

All pipes in the LO_2 feedlihe have an internal diameter

of 43.2 cm and all joints contain teflon coated seals and leak test ports. Flexible joints are fitted in three pipe sections (two in the forward flexible assembly, one in the forward flexible elbow and two in the aft flexible assembly) to provide tolerance for thermal expansion and dynamic motion and seven feedline attachments secure the eight feedline sections at a variety of locations apart from the LO_2 Tank inlet/outlet fitting and the right aft umbilical disconnect plate fitting.

The LO_2 antigeyser line is connected to a manifold on the LO_2 feedline 90° aft elbow (close to the right aft umbilical disconnect plate) at one end, travels along the outside of the LH_2 Tank, enters the Intertank and mates with a flanged joint on the aft dome of the LO_2 Tank at the other end. An aft flexible line turns the flow through 90° from its interface with the LH_2 feedline aft elbow so that a short section lies along the exterior of the LH_2 Tank wall and this is connected to 3 x 6.09 m long straight pipe sections where it joins a 4.52 m long pipe which has a 2.7 cm offset, 1.52 m from the forward flange. This permits the LO_2 antigeyser line to follow the contour of the LH_2 Tank/Intertank interface.

A forward flexible elbow carries forward 1.52 m from the offset pipe and then turns in through the Intertank skin panel to join a forward flexible line which itself turns again to meet a flanged joint on the LO_2 Tank aft dome 11.13° from the tank centreline and 70.25° in a clockwise rotation from the top of the tank. A 10.5 cm diameter, 16 cm high, cylinder is fitted to the LO_2 Tank on the inboard side of the forward flexible line/LO_2 Tank interface with six 0.8 cm bolts. The cylinder is covered with a 800-micron screen.

In total the 7 x 10.16 cm o/d. LO_2 antigeyser pipe sections contain six flexible joints (two in the forward flexible line, one in the forward flexible elbow and three in the aft flexible line) with all pipe sections joined by 12 0.63 cm bolts to each other and to the extreme end locations; 14 sliding and one fixed support positions are provided.

The helium inject line is a 0.36 cm o/d pipe which originates in the Intertank at a tee-joint with the LO_2 vent valve actuation line on the intermediate ring frame immediately aft of the main ring frame 25° counter-clockwise from the Intertank top line. The line then travels along the interior of the Intertank skin panel, exits the Intertank in the vicinity of the extreme aft intermediate ring frame and extends down the side of the LH_2 Tank clamped to the left side of the cable tray from where it is connected to the LO_2 antigeyser line just forward of the right aft umbilical disconnect plate.

LO_2 Tank pressurisation is accomplished *via* an uninsulated 5.08 cm o/d tube which runs from the top of the LO_2 Tank forward cover plate down the entire length of the ET

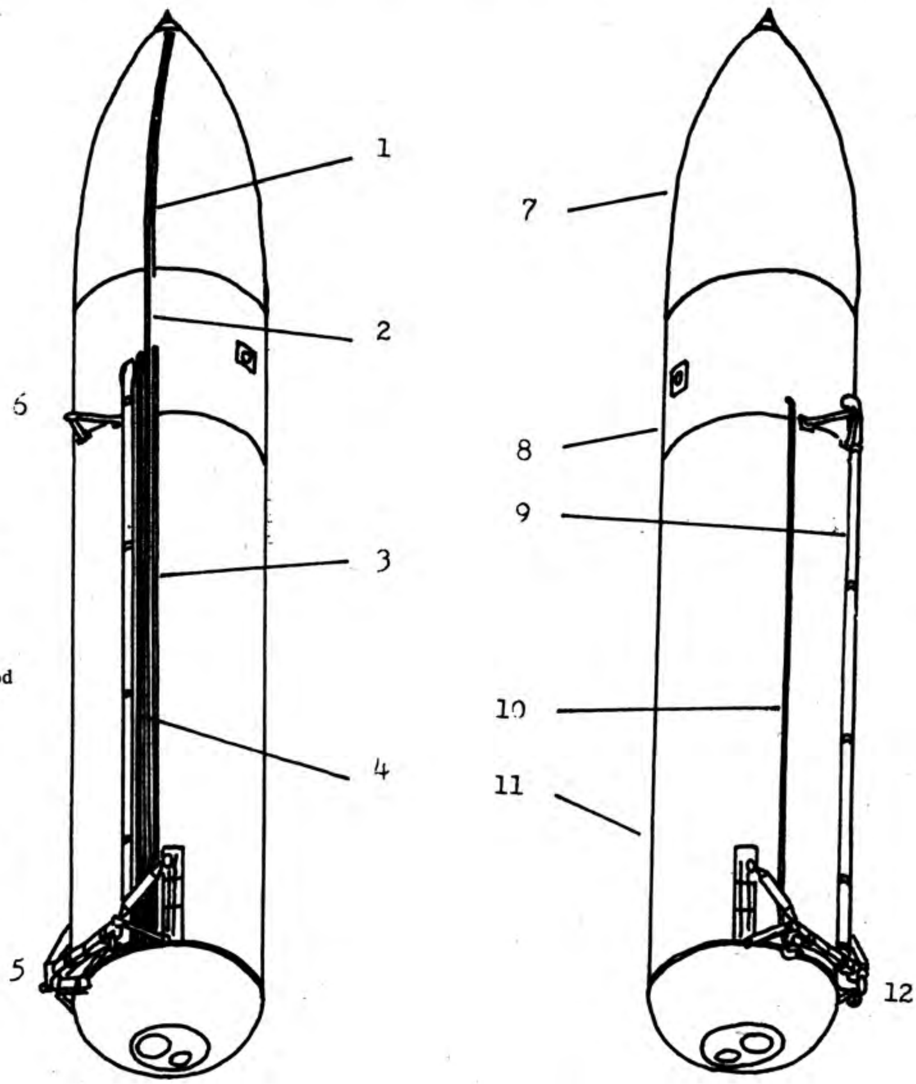


Fig. 1. External Tank Propulsion.

Key:
1. GO_2 vent valve actuation line
2. GO_2 pressurisation
3. Helium inject
4. LO_2 antigeyser
5. Left aft umbilical disconnect
6. Forward Orbiter attachment bipod
7. LO_2 Tank
8. Intertank
9. LO_2 feedline
10. GH_2 pressurization
11. LH_2 Tank
12. Right aft umbilical disconnect

to the right aft disconnect plate where it mates with the GO_2 disconnect fitting. Starting at the right aft umbilical disconnect, the GO_2 line travels 131 cm down toward the LH_2 Tank aft major ring frame and then angles through two 45° bends to lie 90.7 cm along the aft LH_2 Tank barrel where it joins 5 x 6.096 m long straight tube sections which are fixed along the entire length of the LH_2 Tank and Intertank structures (30.48 m) to the immediate left of the LO_2 antigeyser line.

At the Intertank/LO_2 Tank interface it is joined to a 6.096 m long upper transition tube which travels forward along the LO_2 Tank barrel and partially forward along the aft ogive section. Another 6.096 m long line lies along the remainder of the aft ogive section and the forward ogive section to a point about 0.9 m short of the LO_2 Tank forward ring and cover plate assembly. The final section of the GO_2 pressurisation line extends forward from this point on past the LO_2 Tank forward ring and then turns in through a hole in the nose cap and arches back down 35.6 cm to enter the LO_2 Tank through a central orifice in the forward LO_2 Tank cover plate directly behind the lightning rod, (Fig. 2). All nine line sections are joined to each other by 8 x 0.8 cm bolts with seals and leak test ports between any two interface flanges. A total of 33 sliding and two fixed supports retain the GO_2 line in position.

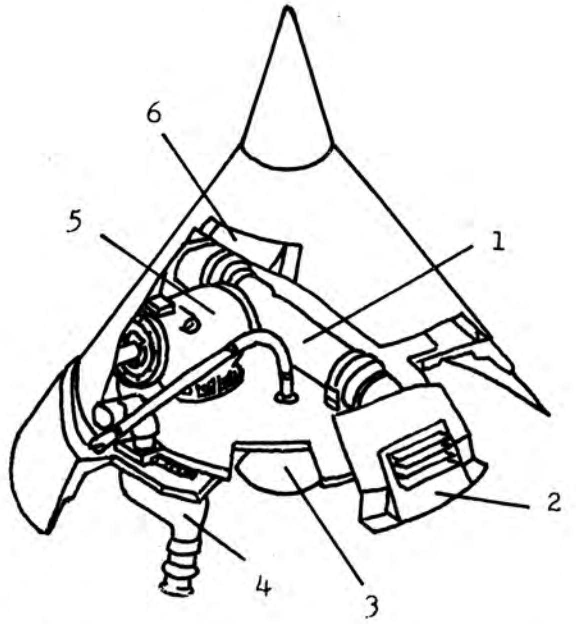
The central orifice in the LO_2 Tank forward cover plate is matched on the interior by a conical diffuser which flares from an I.D. of 10.5 cm to 30.48 cm in a length of 17.8 cm. A 3.5 cm orifice carries GO_2 through the forward cover plate before opening to the 10.5 cm i/d of the diffuser. The diffuser is attached to the aft face of the forward cover plate by 8 x 0.8 cm bolts and it supports three perforated plates with 0.6 cm holes and open areas of 49.5%, 51.8% and 52.7%.

A LO_2 Tank vent/relief subsystem is attached to the forward face of the LO_2 Tank forward cover plate inside the nose cap to the rear of the lightning rod, (Fig. 2). A hole in the forward cover plate allows GO_2 to flow from the LO_2 Tank to a 17.8 cm diameter inlet port leading in to a vent/relief valve and manifold assembly. The valve assembly is attached to the forward cover plate by 12 x 0.9 cm bolts and consists of main and pilot poppet valves, spring, piston and check valve. A 13 cm i/d outlet on the main valve provides a 10.2 cm long flow path from this point to a tee going 50.8 cm in one direction and 15.2 cm in the other direction (180° to the former) to two diametrically opposed open vent louvres mounted in the side of the nose cap immediately forward of the cover plate/nose cap join line. GO_2 is vented through these two louvres which lie to left and right of the ET longitudinal axis.

A 0.95 cm diameter vent valve ground actuation line extends from the Intertank umbilical plate, follows a circuitous route round ring frames and rolling ties, reduces to a diameter of 0.63 cm, ties with the helium inject line (see above, this section) and finally emerges from the Intertank adjacent to the extreme forward intermediate ring frame and about 30° clockwise from the main ET longitudinal axis. From here it enters the forward cable tray and is carried up to the LO_2 Tank nose cap where it enters the interior and mates with the actuation port on the GO_2 vent/relief valve.

The tumbling subsystem consists of a 5 cm pyro-valve mounted to the front of the LO_2 Tank forward ring frame 16° clockwise from the tank top centreline by 8 x 0.8 cm bolts, a manifold, gimbal joint and a lance. The 4.3 m long lance is secured to the interior face of the forward ogive nose section by four A-frame supports displaced 31.5° in a clockwise direction and the gimbal joint connects the lance to the manifold which is fitted to the LO_2 Tank forward ring by 12 0.8 cm bolts.

The pyro-valve exit nozzle emerges from the forward face



Key:
1. GO_2 vent/relief manifold
2. GO_2 vent louvres
3. GO_2 diffuser
4. Tumble system pyro-valve
5. GO_2 vent/relief-valve
6. Forward cable tray fairing

Fig. 2. External Tank nose cap assemblies.

of the valve housing, turns through 90° and protrudes through the wall of the nose cap. The pyro-valve is fired by signals from the Orbiter which generates pressure, moves a piston and shears a gate permitting LO_2 ullage to exhaust GO_2 through the exit nozzle.

The LH_2 feedline begins at a 152 cm siphon inlet situated 17.8 cm from the extreme rear of the LH_2 Tank, offset 8° from the longitudinal axis. A 88.9 cm LH_2 Tank internal bellows pipe (43.2 cm i/d) links the siphon to a port on the LH_2 Tank aft dome, located 20.16° counterclockwise from the tank top centreline and immediately aft of the LH_2 Tank aft major ring frame. Flange fittings at siphon and dome ends each accommodate 36 0.95 cm securing bolts. The aft major ring frame supports a bracket to stabilise the internal bellows pipe. The external bellows section takes H_2 from the internal feedline/aft dome port assembly to the left aft disconnect plate and is a 106.8 cm long jacketed articulation fitted to the aft dome port by 36 x 0.95 cm bolts and to the left aft disconnect plate by 48 0.8 cm bolts. Additional struts from the aft Orbiter support structure crossbeam secure the flexible bellows.

The LH_2 recirculation line is a 10.2 cm diameter single section pipe about 7.6 m long connected to the left aft disconnect plate at one end and to a fitting on the LH_2 Tank aft dome, behind the LH_2 feedline port, at the other end. The LH_2 Tank aft dome fitting is merely an opening in the tank dome with a flange for securing the recirculation line by 12 x 1.6 cm bolts, a similar bolt arrangement that secures the other end to the disconnect plate. The pipe incorporates a jacketed bellows assembly.

The LH_2 Tank pressurisation subsystem takes a 5 cm o/d line from the aft left umbilical disconnect plate, along the LH_2 Tank wall offset 30° counterclockwise from the tank top centreline, through the Intertank wall and across to the LH_2 Tank forward dome end-cap where it penetrates the tank volume and ends in a tee-shaped diffuser just inside the dome. The rear line section starts at the aft left umbilical

disconnect panel, extends down toward the LH_2 Tank 1.28 m and out 11 cm and turns 90° to lie 94 cm along the LH_2 Tank. From here 4 x 606.68 cm long straight sections carry forward 24.26 m along the LH_2 Tank barrel sections to an upper line. This penetrates the Intertank skin, lies 3.96 m along the forward dome and then curves back 30.5 cm to a juncture on the forward dome end-cap. The six line sections can accommodate six flexible joints and 15 supports secure the pipes to structural assemblies. All connections are made with 8 x 0.8 cm bolts. A V-shaped strut bipod is used inside the Intertank structure to support the GH_2 line.

The GH_2 diffuser is tee-shaped with a 7.6 cm inlet tube leading to a 12.7 cm diameter cross tube, 76.2 cm long and 17.8 cm inside the LH_2 Tank dome. It is attached to an inlet flange with 8 x 0.8 cm bolts and carries 1,092 x 0.32 cm perforations surrounded by 20.3 cm diameter, 31.4 cm long, wire cloth cylinders at each end. A total exit area of 0.39 m^2 is available providing a limited GH_2 velocity of 18.2 m/sec. for minimum disturbance of the LH_2.

A LH_2 vent/relief subsystem connects a GH_2 vent/relief valve assembly to the Intertank umbilical disconnect plate. The valve is attached to a vent duct in the LH_2 Tank forward dome end-cap by 12 x 0.95 cm bolts 120.6 cm from the centreline of the tank along a line situated 120° counter-clockwise from the tank top centre. From here the same bolt arrangement secures a 259.6 cm long double-angle GH_2 vent duct. This pipe terminates at the Intertank umbilical disconnect plate where it is secured by 16 x 0.8 cm bolts. A support strut is connected to brackets on the forward face of the dome end-cap and the vent duct contains a bellows assembly at the angle bend, about 31 cm from the vent valve.

Intertank purging is accomplished with a 0.95 cm diameter steel tube extending from the Intertank umbilical disconnect plate and forward of the main ring frame (about 61 cm) where it branches into three lines. One line follows the curvature of the ring frame about 50° and terminates at the electronic enclosure for the DFI (Development Flight Instrumentation) and the other two travel in opposing directions around the main ring frame to within 10° of meeting on the opposite wall of the Intertank. A total of 78 x 0.6 cm holes are drilled in the opposing semi-ring branches and GN_2 from a ground supply (to the umbilical plate) flows into the Intertank through these holes at 17 kg/min. limiting hazardous gas content to a maximum 3.5%.

A hazardous gas detection system (HGDS) provides a line from the Intertank umbilical disconnect plate up to the extreme forward intermediate ring frame. It then tees and the two opposing branches follow the curvature of the Intertank wall where the ends terminate, 180° apart. Two orifices, 0.29 cm and 0.45 cm in diameter, at the tube ends permit a flow of Intertank gas to the HGDS suction lines and out through the Intertank umbilical disconnect to ground monitoring mass spectrometers. Purge gases, He for the LH_2 Tank and N_2 for the LO_2 Tank, are introduced through the propellant feedlines and pressurisation lines and no unique equipment is carried for this purpose.

Electrical System

The electrical system discussed here represents the operational instrumentation applied to all ET units. DFI equipment will be fitted to the Main Propulsion Test Article and the first six production tanks in support of the six Shuttle development flights.

A total of 38 sensors are carried by the ET and these monitor ullage temperature, ullage pressure, liquid level and depletion and GO_2 and GH_2 vent valve positions. Level and depletion sensors in the LO_2 Tank display 102%, 100.15%, 100%, 98.86%, 98%, 5% and 2%; sensors in the LH_2 Tank show 102%, 100.3%, 100%, 99%, 99.7%, 98%, 5% and 2%.

External cables are carried in cable trays which are located along the length of the LH_2 and LO_2 Tanks displaced 32° clockwise from the ET top centreline. The forward tray extends from the nose cap, just below the lightning rod, to the forward intermediate ring frame of the Intertank assembly. The rear cable tray begins at the aft Intertank ring frame and runs down the LH_2 Tank barrel section to the aft main ring frame. Other cable trays are fitted to the aft umbilical disconnect crossbeam and the left and right rear Orbiter attachment struts. The Intertank accommodates two disconnect panels each of which carry five multi-pin electrical connectors. Feed-through 37-pin connectors are attached to the forward and aft areas of the LO_2 Tank and to the rear of the LH_2 Tank near to the left rear Orbiter attachment strut. The two Intertank panels carry electrical lines from the interior to the two cable trays.

The ET/Orbiter left aft umbilical disconnect plate supports six electrical connectors and the right disconnect carries seven; two on each side support Orbiter/ET functions and four and five (on respective sides) serve Orbiter/SRB functions. Electrical connection between the Orbiter and the two SRB units follows a path from the ET/Orbiter left and right aft umbilical disconnect panels round the LH_2 Tank aft main ring frame to the ET/SRB aft upper attachment locations 180° apart on left and rights sides of the ET.

The 47.7 cm long lightning rod is 17.5 cm in diameter where it meets the LO_2 Tank nose cap and is tip rounded to a radius of 0.4 cm, designed to accommodate a first strike of 200,000 amperes followed by a second strike of 50,000 amperes sustained by the main body of the ET. The rod is electrically bonded to the GO_2 pressurisation line fairing (where it enters the nose cap) and electrically conductive paint over the TPS on the nose cap carries the strike to the GO_2 line. The 0.2 cm thick LH_2 Tank barrel wall panels are sized so as to accommodate a lightning strike without penetration. It is worth noting here that the intervals between launch of a Shuttle will be reduced to a level where launch pad "holds" due to meteorological conditions become unacceptable and the design of the structures reflect a desire to lower launch constraints.

Thermal Protection System

The Thermal Protection System (TPS) is primarily responsible for inhibiting the accumulation of ice on the exterior surface of the ET during on-pad conditions when cryogenic propellants are loaded, maintaining LO_2 and LH_2 boiloff rates below the vent valve threshold, reducing air liquefaction on the LH_2 Tank and profiling the breakup of the ET during descent so that all fragments fall within a designated area.

Where large quantities of cryogenic propellants are kept in thin-skinned tanks the inevitable accumulation of ice on the exterior wall is a product of the absence of insulation to buffer the super-cold temperatures on the inside from atmospheric temperatures on the outside. Predictable build-up of ice has never seriously compromised engineering design in cryogenic stages where launch vehicles are stacked in tandem but with the parallel-stack concept of the Shuttle design large quantities of ice breaking free during engine thrust build-up and ascent has been seen as a real problem for the damage it may cause to Orbiter TPS tiles. It has been necessary, therefore, to provide the ET with a buffer zone which prevents ice build-up and at the same time isolates the cryogenic ET from possible conductive paths to the Orbiter and SRB structures.

Two principal types of TPS material are applied to the ET: SLA-561 and CPR-421. The latter is dominant over much of the ET structure and consists of a fluorocarbon-

blown, rigid foam insulation with low viscosity potential; a polyisocyanurate foam with thermal stability exceeding standard urethane foams protected from sunlight, UV radiation and moisture by a sealer, (Fig. 3). A Desota primer is applied to the aluminium skin of the ET to improve CPR-421 adhesion and protect the metal. CPR-421 is applied at temperatures between 27°C and 38°C and the spray-on application leaves a rough and uneven surface finish.

SLA-561, also a spray-on foam insulation, is a low-density silicone rubber composite with ingredients of charformers, refractory materials and reinforcing agents applied directly over a silicone primer and a polysiloxane adhesive coating and sealed with a white elastomeric silicone coating to protect the material from moisture. It is applied over small areas on its own or under CPR-421 where high heat environments and high ice accumulation levels dictate additional insulation. The SLA-561 can be pre-moulded to shape for high heat areas or sprayed directly to the primer and adhesive on the aluminium surface.

The nose cap attached to the forward LO_2 Tank ogive section is covered with a layer of 0.89 cm thick SLA-561 (excluding the lightning rod) and the entire exterior surface of the LO_2 Tank ogive section and barrel section is covered with CPR-421 2.54 cm thick. The extreme forward section of the LO^2 Tank ogive section carries insulation which is contoured to a thickness of 5.08 cm at the ogive/nose cap interface, however. The LO_2 Tank aft dome is left uninsulated and acts as a heat sink for the insulated Intertank by purging the interior of the Intertank with GN_2 through the distribution manifold. The Intertank exterior is insulated with CPR-421 to a depth of 1.27 cm over the stringers giving a corrugated appearance minimised due to thicker accumulations between the stringers. The Intertank access door is uninsulated.

The cylindrical sections of the LH_2 Tank are covered with CPR-421 2.54 cm thick and the exposed aft dome and end-cap is coated with the same material 5.08 cm thick to protect the aft end from Orbiter SSME heat. The forward dome is covered with a 1.27 cm thick application of CPR-421 to prevent Intertank GN_2 freezing on to the forward LH_2 Tank area.

A 4.27 m^2 area on the aft section of the Intertank and the forward section of the LH_2 Tank is covered with SLA-561 overlain with a coating of CPR-421 to inhibit thermal conductivity along the ET/Orbiter forward attachment bipod. The 1.49 m^2 area on the Intertank is coated with 0.25 cm of SLA-561 overlain with 1.27 cm of CPR-421. Coatings on the 2.78 m^2 area on the LH_2 Tank forward section are 0.5 cm of SLA-561 and 2.54 cm of CPR-421.

SLA-561 is applied to the aft ET/Orbiter attachment struts and a combination SLA/CPR coating covers the forward and aft cable trays and underlies the LO_2 feedline and the GH_2 pressurisation line. Application of the designated thicknesses of TPS material increases ET dimensions to a length of 47.286 m and a diameter of 845.82 cm.

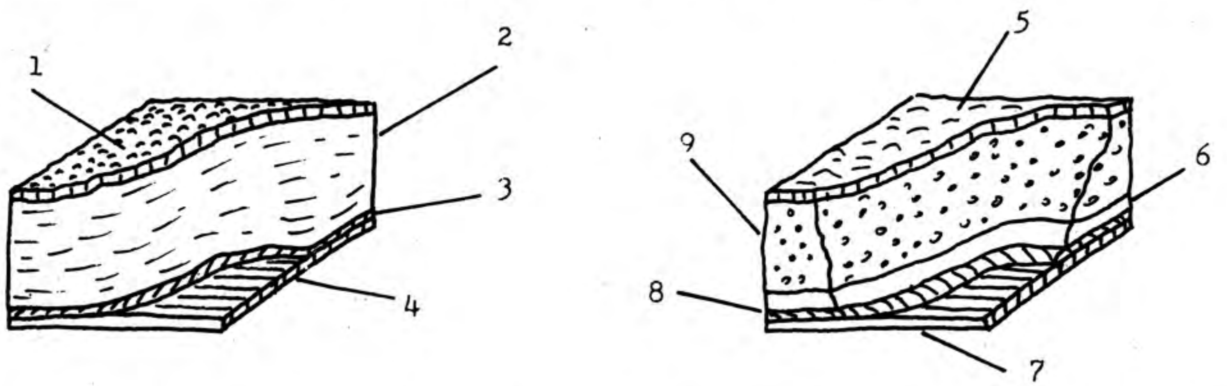
Operations

Although a number of ET delivery and flight preparation events may change from the currently scheduled sequence the following description represents the pre-flight plan as accepted at the time of writing.

Manufacture of ET elements and fabrication into a flight-rated article takes place at the Martin Marietta plant located at the NASA Michoud Assembly Facility in New Orleans, Louisiana. The completed ET is mounted on a wheeled transporter to facilitate delivery and provide a dessicant breather system, temperature and humidity monitoring equipment and a device for measuring ET accelerations in transit. The breather system utilises the LO_2 and LH_2 feedlines. NASA will use barges procured for Saturn launch vehicle stage delivery to the Kennedy Space Center to deliver the ET to either the East Coast launch site (from 1979) or the Vandenberg AFB (from 1982). Two barges are currently available but consideration is being given to the procurement of a new and larger barge which will be capable of delivering four ET units per trip.

After a journey of about five days the ET will arrive at KSC and receive immediate on-barge inspection before removal, on the wheeled transporter, to the transfer aisle in the Vehicle Assembly Building (VAB) at Launch Complex 39. If the ET is not immediately required it will be moved to one of the VAB storage cells. In the normal processing flow, however, it is raised from the transporter to a vertical position in a VAB Checkout Cell by two overhead cranes (226,800 kg and 158,760 kg lifting capacity). The 158,760 kg crane is disconnected and the ET is moved by the other crane to a wall-mounted position for a complete inspection of TPS material, tank interiors, umbilical connections, etc., and the installation of ground support and launch processing system equipment. Final closecut of the ET occurs here.

At T-71 hr. (71 hr. before launch) the ET is moved vertically from the Checkout Cell to the Integration Cell by a sling and the 226,800 kg capacity crane. Prior to this two Solid Rocket Boosters will have been erected vertically on a Mobile Launch Platform (MLP) using data from an optical alignment check of the ET/SRB attachment points while the ET is still in the Checkout Cell; SRB stacking on the MLP can be adjusted to compensate for ET/SRB attachment



Key: 1. V455 M Sealer
2. CPR-421
3. 513-707 Primer
4. Aluminium surface
5. SDC92-007 Sealer
6. GX-6300 Adhesive
7. Aluminium surface
8. DC-1200 Primer
9. SLA-561

Fig. 3. TPS material application.

points which may vary in alignment by fractions of a centimetre.

When the ET is brought to the Integration Cell the forward attachment points are secured to the two Boosters followed by the six aft fittings to fully mate the ET with the SRBs. At T-62 hr. the Orbiter arrives at the VAB transfer aisle from the Orbiter Processing Facility and is lifted to a vertical position from where the aft ET/Orbiter attachment fittings are secured followed by forward attachment bipod mating. Umbilicals and feedlines are then connected and a final interface verification precedes rollout to the pad at T-24 hr. During stacked operations the ET LO_2 and LH_2 Tanks are pressurised 260 g/cm^2 above atmospheric pressure to prevent structural damage.

At T-17 hr., with the Shuttle and MLP at the pad, facility servicing lines are mated to the Intertank umbilical assembly and the MLP is plugged in to the ground services, this activity being completed by T-10.5 hr. Between T-12.5 hr. and T-10.5 hr. the ground facility LO_2 and LH_2 services are purged ready for ET tank purging from T-10 hr. to T-6 hr., thereby ensuring an uncontaminated propellant flow path at ET and pad ends of the supply. GN_2 is fed through LO_2 Tank feedlines and GHe is flushed through the LH_2 feed system.

Propellant loading begins at T-2 hr. after Orbiter cargo bay closeout and Payload Changeout Room* retraction with vent valve opening, chilldown and slow fill to a 2% level and fast fill (18,925 litres/min. LO_2 and 45,420 litres/min. LH_2) to 98% by T-45 min. Fill flow is reduced to accomplish a 100% level and a slow replenishment flow is sustained until T-3 min. 2 sec. for LO_2 and T-1 min. 52 sec. for LH_2 at which times the vent valves are closed. Propellant flows through the Orbiter umbilical interface and feed systems. The LO_2 antigeyser line prevents the accumulation of GO_2 in the feedlines which could otherwise cause a reduced ullage temperature and a loss of pressure resulting in LO_2 Tank deformation. The helium injection flow initiates antigeyser line flow by literally foaming the LO_2 in the antigeyser line, reducing the pressure and causing the LO_2 to flow upward against gravity.

In the Orbiter SSME preconditioning phase LH_2 is recirculated from the engine inlets and in the final 15 min. of the countdown engine conditioning is achieved by a subcooled LO_2 flow from the pad facilities to supplement the LO_2 bled through the engines in the preconditioning phase. LO_2 vapour is vented to the atmosphere through two nose cap louvres (Fig. 2) and the LH_2 vapour is delivered to the Intertank umbilical plate *via* the LH_2 vent/relief subsystem and from there to a burn pond. Intertank purging during propellant loading is accomplished *via* a GN_2 supply and the hazardous gas detection system is connected to a ground facility mass spectrometer for sensing H_2, O_2, He and Ar products.

Tank pressurisation begins at T-2 min. 23 sec. when GO_2 flows to the LO_2 Tank ullage volume and brings it up to between 1,406 g/cm^2 and 1,546 g/cm^2 at maximum, about 71 g/cm^2 below the minimum vent/relief valve trip pressure. LH_2 Tank pressurisation begins at T-1 min. 20 sec. reaching a level between 2,250 g/cm^2 and 2,390 g/cm^2, again about 71 g/cm^2 below the minimum LH_2 vent/relief valve actuation level. Ground facility He maintains these pressures until launch commit and lift-off when the umbilicals disconnect.

SSME ignition comes at T-4 sec. and propellants vapourised in the engine heat exchangers are bled off and delivered to the tanks to supplement ullage pressure. Tank ullage pressure sensors feed data to the Orbiter so that bi-level modulation can sustain tank pressures within the above indicated bands. Lift-off comes immediately after SRB ignition, the pitch and roll programme beginning at tower clearance (T + 5 sec.). Staging will normally occur at T + 126 sec. and an altitude of 43.5 km.

ET/Orbiter separation comes within 10 sec. of SSME shutdown (T + 488 sec.) which is commanded by the Orbiter guidance, navigation and control subsystem. A propellant reserve is provided but in conditions where the excess is depleted (due to low SRB thrust, perhaps) engine cutoff is initiated by a signal from the LO_2 depletion sensors in the Orbiter feed duct. Because of the severe mechanical damage which could occur to the reusable SSME units if a LO_2-rich mixture should flow through the engines, a 499 kg LH_2 bias is available but if this is used due to an anomalous imbalance in mixture ratio LH_2 sensors in the aft dome send an override engine shutdown command when depletion reaches 408 kg remaining.

Shortly before separation the crew fire the pyro-tumble valve which releases GO_2 ullage from the LO_2 Tank and at pyrotechnic separation the nose of the ET pitches away from the Orbiter under the influence of this propulsive vent, causing the ET to tumble at a rate of one revolution every 7.2 to 36 sec., the rate depending upon residual propellant quantity. Separation would normally occur at an altitude of 113.4 km and the tumble action prevents atmospheric skip and causes the ET to break up at a height of 56 km, thus ensuring that all fragments fall within a 185 x 1,111 km designated area.

Preparations for the operational ET flight phase requires nine complete development structures and three partial structures. In 1977 Martin Marietta delivers an Intertank Test Article, LO_2 and LH_2 Static Test Articles, the Main Propulsion Test Article (MPTA) and the ET Static Test Article (ETSTA). The MPTA is the first fully assembled ET and was delivered last July to the National Space Technology Laboratories (NSTL, formerly the Mississippi Test Facility or MTF) where it is undergoing tests with a simulated Orbiter midbody and boattail complete with operational engine units. In a series of 15 firings the programme verifies dynamic interaction between subsystems and propellant filling, venting and pressurisation, verifies thermal modelling techniques and thermal protection systems, monitors propellant flow and feedline characteristics and evaluates the planned modes of transportation, handling and storage.

The ETSTA is to be delivered in December (1977) and will be used in a series of structural tests to fully qualify the elements in an assembled configuration. The Ground Vibration Test Article (GVTA) will be delivered to the Advanced Dynamic Test Stand at the NASA Marshall Space Flight Center at the end of March 1978, joining Orbiter 101 which will have been delivered to that facility from approach and landing tests with a Boeing 747 earlier in the month, (see part 5 in this series).

Mated to the Orbiter and two Solid Rocket Boosters the GVTA will participate in measurements of frequency, mode shapes and damping characteristics of the complete Shuttle configuration. POGO (vertical oscillation) analysis, structural load measuring and flutter analyses, will be accomplished together with amplitude-frequency surveys of 0.2 Hz to 30 Hz (50 Hz in the longitudinal axis) modes and simulated propellant mass interaction. The ground vibration tests will be completed by December 1978 and the ET will be refurbished for an operational Shuttle flight after the first six Shuttle development missions. The six pre-production ET units will be fitted with DFI equipment and ET-1 (the first of these) will be delivered to KSC in December 1978 ready for the first manned orbital Shuttle flight in March 1979. Details of programme planning and ET production schedules will be outlined in subsequent reports.

* *The Payload Changeout Room (PCR) is a pivoted cleanroom facility alongside the Shuttle and permanently attached to the launch pad. It will swivel round to encapsulate the Orbiter cargo bay for payload transfer in a protected environment.*

T 36

SATELLITE DIGEST - 113

A listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information sources include the Space Department of the Royal Aircraft Establishment at Farnborough, NASA, Novosti and both the popular and specialist press. For a more detailed summary, see Satellite Digest – 111, January, 1978.

Continued from February issue, p. 72]

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Molniya-1AP 1977-82A	1977 Aug 30.76 10 years?	Cylinder-cone + 6 panels + 2 antennae 1000?	3.4 long 1.6 dia	445 483	40785 39873	62.83 62.85	735.58 717.77	Plesetsk A-2-e USSR/USSR (1)
Cosmos 948 1977-83A	1977 Sep 2.38 12.84 days (R) 1977 Sep 15.22	Cylinder + sphere + cylinder-cone 5500?	6 long? 2.2 dia?	217	235	81.36	89.04	Plesetsk A-2 USSR/USSR (2)
Voyager 1 1977-84A	1977 Sep 5.54	Octagon + dish + booms 800	1.9 dia 1.5 high 3.7 dish	helion	heliocentric orbit			ETR Titan 3-Centaur NASA/NASA (3)
Cosmos 949 1977-85A	1977 Sep 6.73 29.5 days (R) 1977 Oct 6.2	Cylinder + sphere + cylinder-cone? 5500?	6 long? 2.2 dia?	177 149 177	325 364 364	62.80 62.80 62.80	89.50 89.61 89.89	Plesetsk A-2 USSR/USSR (4)
Cosmos 950 1977-86A	1977 Sep 13.64 13.6 days (R) 1977 Sep 27.2	Sphere + cylinder- cone? 5000?	5 long? 2.2 dia?	205	282	62.81	89.36	Plesetsk A-2 USSR/USSR
Cosmos 951 1977-87A	1977 Sep 13.83 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	968	1017	82.97	104.98	Plesetsk C-1 USSR/USSR (5)
Cosmos 952 1977-88A	1977 Sep 16.60 600 years?	Cone-cylinder?	6 long? 2 dia?	251 910	265 998	64.97 64.94	89.65 104.13	Tyuratam-Baikonur F-1-m USSR/USSR (6)
Cosmos 953 1977-89A	1977 Sep 16.61 12.6 days (R) 1977 Sep 29.2	Cylinder + sphere + cylinder-cone? 5500?	6 long? 2.2 dia?	180 151	330 300	62.80 62.81	89.58 89.00	Plesetsk A-2 USSR/USSR (7)
Cosmos 954 1977-90A	1977 Sep 18.58 600 years?	Cone-cylinder?	6 long? 2 dia?	251	265	64.98	89.65	Tyuratam-Baikonur F-1-m USSR/USSR (8)
Cosmos 955 1977-91A	1977 Sep 20.05 60 years	Cylinder + 2 vanes + 2500?	5 long? 1.5 dia?	630	641	81.24	97.46	Plesetsk A-1 USSR/USSR
Ekran 2 1977-92A	1977 Sep 20.73 indefinite	Cylinder + 2 paddles + rectangular array 5000?	5 long? 2 dia?	35580	35622	0.40	1426.55	Tyuratam-Baikonur D-1-E USSR/USSR (9)
Prognoz 6 1977-93A	1977 Sep 22.04 10 years?	Cylinder + 4 vanes 910?	1.8 long? 1.8 dia?	488	197867	65.00	5688	Tyuratam-Baikonur A-2-e USSR/USSR (10)
1977-94A	1977 Sep 23.78 10 weeks	Cylinder 3000?	8 long? 1.5 dia?	125	352	96.49	89.30	WTR Titan 3B-Agena D DoD/USAF
Cosmos 956 1977-95A	1977 Sep 24.43 6 years			355	863	75.83	96.89	Plesetsk C-1 USSR/USSR
Intercosmos 17 1977-96A	1977 Sep 24.69 6 years	Octagonal ellipsoid + panels 550?	1.8 long? 1.5 dia?	466	514	82.96	94.44	Plesetsk C-1 USSR/USSR (11)
Salyut 6 1977-97A	1977 Sep 29.29 20 months?	Stepped cylinder + 3 vanes 18900?	14 long 4.15 max dia	214 329	256 353	51.59 51.62	89.14 91.29	Tyuratam-Baikonur D-1 USSR/USSR (12)
Cosmos 957 1977-98A	1977 Sep 30.41 12.9 days (R) 1977 Oct 13.3	Cylinder + sphere + cylinder-cone 5500?	6 long? 2.2 dia?	171 150	361 351	64.97 64.98	89.82 89.51	Tyuratam-Baikonur A-2 USSR/USSR (13)

Supplementary notes:
(1) Orbital data are at 1977 Aug 31.8 and 1977 Sep 13.9.
(2) A 2 m diameter, 0.5 m deep cylindrical experiments package was ejected from 1977-83A during 1977 Sep 14; it is designated 1977-83C.
(3) Second of NASA's pair of interplanetary spacecraft investigating the outer planets (see last month's table). It is due to fly past Jupiter at 1979 March and Saturn 1980 November.
(4) Orbital data are at 1977 Sep 7.3, 1977 Sep 20.5 and 1977 Sep 23.5. A redundant manoeuvring engine, designated 1977-85D, was ejected during 1977 Oct 5.
(5) Cosmos 951 may be a navigation satellite.
(6) One of a pair of ocean surveillance satellites (see note 8 below). The orbit was raised about 1977 Oct 8.5 at which time a rocket and "platform" separated and remained in the lower orbit. The manoeuvre to the higher orbit is probably to prevent a nuclear generator from disintegrating on re-entry while still dangerously radioactive. Orbital data are at 1977 Sep 18.6 and 1977 Oct 8.7.
(7) Orbital data are at 1977 Sep 17.2 and 1977 Sep 22.2. A redundant manoeuvring engine, designated 1977-89C, was ejected during 1977 Sep 28.
(8) Second of a pair of ocean surveillance satellites operating together in orbit. See note 6 above.
(9) Geostationary communications satellite broadcasting TV programmes to small communities in Siberia and the far north of the USSR. Ekran 2 carries the designation Statsionar-T.
(10) Prognoz 6 is the latest in a series of satellites investigating the magnetosphere and the solar wind.
(11) International co-operative satellite investigating the energies of charged particles in near Earth space. Experimental equipment was built in the USSR, Hungary, Roumania and Czechoslovakia.
(12) Civilian type manned space station, similar to Salyut 4 but with two docking units. The first attempt to place a crew aboard was using the Soyuz 25 ferry. See next month's table.
(13) Orbital data are at 1977 Oct 1.3 and 1977 Oct 2.3. A redundant manoeuvring engine, designated 1977-98E, was ejected during 1977 Oct 12.

Amendments and decays:
1972-81A, Molniya-1W probably decayed 1977 Nov 6.
1973-07A, Molniya-1Y probably decayed 1977 Nov 1.
1974-103A, the main fragment of Cosmos 699 after its explosion decayed 1977 Oct 16, lifetime 1027 days.
1975-67A, Cosmos 750 decayed 1977 Sep 29.9, lifetime 805.5 days.
1977-57A, the retrograde Meteor weather satellite was launched southward from Tyuratam-Baikonur, not Plesetsk as originally listed.

SOCIETY NEWS

SOUTHERN CALIFORNIA BRANCH

The Southern California Branch has presented its second annual symposium and elected officers for the coming year.

The symposium, *Beyond Mars: Exploration of the Outer Planets,* was presented the afternoon of 31 October in the Kinsey Auditorium of the California Museum of Science and Industry. Eric Burgess, chairman of the first symposium, presided for this one as well, and the keynote was given by Gentry Lee, Manager of the Mission Design Section at the Jet Propulsion Laboratory.

Dr. William Dixon of TRW spoke on the accomplishments of the Pioneer 10 and 11 missions to Jupiter. John Casani, Charles Kohlhase, and Dr. Edward Stone of JPL and the California Institute of Technology described plans for the recently launched Voyager (nee Mariner Jupiter/Saturn) spacecraft.

Three JPL speakers then examined possible Outer Planets missions for the 1980's. Jesse Moore discussed the forthcoming Jupiter Orbiter/Probe mission; John Beckman spoke on post-Voyager exploration of Saturn; and Dr. Louis Friedman explained concepts for solar electric and solar sail propulsion systems which would allow spacecraft to match orbits with comets.

Speakers coordinator for the symposium was George Carlisle, who also handled publicity with Charles Carr. Production staging was handled by Robert Frampton, Michael Humnicky, Joyce Hailey and Anne Daniel.

At their meeting on 16 November, about 120 BIS members and guests heard Dr. John Lilly speak on *Interspecies Communications.* A pioneer in the study of cetacean intelligence, Dr. Lilly argued that communication between man and dolphin would provide useful experience for the future decipherment of extraterrestrial communications, and of considerable value in itself.

Human beings may not be intelligent enough to ever communicate sensibly with the great whales, but the dolphin brain in sufficiently small that we may meet as equals. Dolphins are also vocally versatile, enough so that they can mimic human speech. The reverse is not true, so Dr. Lilly is proposing a computer interface between the two species, to serve as an automatic dictionary-cum-translating device.

Elections to the Board of Governors of the Southern California Branch were held afterward. Officers re-elected were Robert V. Frampton (President), George Carlisle (Executive Secretary), Michael Humnicky (Treasurer), and Mike Shupp (Corresponding Secretary). Anne Daniel and Joyce Hailey were re-elected to the Board as members.

New members of the Board are Charles Carr and Adrian J. Hooke. Mr. Hooke, returned to Southern California after two years with the European Space Agency, was the original organiser and first president of the BIS - SCB.

Robert Budica, previously a member of the Board, was elected Vice President, succeeding Wayne Hollenbeck.

Meetings of the Branch are held at approximately one month intervals at the California Museum of Science and Industry in Los Angeles. For more information, write: Mike Shupp / 10000 Imperial Highway, Apt. F-119 / Downey, California 90242.

"Planets and Life"

The 1976/7 Lectures with the theme of *"Planets and Life"* have now been collected together to appear in the April 1978 issue of *JBIS.*

Papers to be published range from the origin of planetary systems, and life itself, to its development, the selection processes and the possible existence of other exotic life forms. The treatment is purely factual throughout, which gives the issue a particular value as an excellent but topical appraisal of life and its development for tutorial purposes.

The current (1977/8) lecture series of the *"Exploration of the Planets"* will also appear in a Special *JBIS* issue in due course.

Those members who do not normally receive *JBIS* but who would particularly like to have the *"Planets and Life"* issue may purchase it as a single copy (subject to supplies being available) at a cost of £1.00 ($2.00) post free.

Wills and Legacies

Members who might wish to consider donating to the Society some gift of books, paintings, money, etc. by legacy in their wills are invited to write to the Executive Secretary for a copy of the explanatory notes on the procedure to be adopted.

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: Tel: 01-821 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor 12, Bessborough Gardens, London, SW1V 2JJ.

Opinions in signed articles are those of contributors, and do not necessarily reflect the view of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Western Branch
Theme **ENVIRONMENTAL FILM SHOW**
The programme will include the following films:

(a) Question of Life

(b) The Pollution Solution

(c) The Fractured Look

(d) Universe

To be held in the Main Engineering Lecture Theatre, Queen's Building, University Walk, Bristol, on **10 February 1978**, at 7.15 p.m.

Admission tickets are not required. N.B. No university car parking facilities are available but there are Public Car Parks at Park Row, Berkeley Place, and limited parking in roads around the University Precinct.

Lecture
Title **THE OUTER PLANETS** by Dr. G. E. Hunt.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **2 March 1978**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Lecture
Title **MINOR BODIES IN THE SOLAR SYSTEM** by Dr. D. W. Hughes.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **15 March 1978**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Main Meeting
Theme **OTS AND THE EUROPEAN TELECOMMUNICATIONS PROGRAMME**
A one day Symposium to be held at University College, Gower Street, London, W.C.1. on **1 June 1978.**

Offers of Papers are invited. Further information is available from the Executive Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ, England.

15th European Space Symposium
Theme **APPLICATIONS SATELLITES**
To be held in Bremen, Germany, on **8-9 June 1978.** Co-sponsored jointly by the DGLR, AAAS, AIDAA and BIS.
Subject areas will emphasise the following aspects:

(1) Telecommunications Satellites.

(2) Meteorological/Remote Sensing Satellites, User and Ground Facilities.

Offers of papers are invited. Further information is available from the Executive Secretary.

29th I.A.F. Congress
The 29th Congress of the International Astronautical Federation will be held in Dubrovnik, Yugoslavia, from **1-8 October 1978.**

Further details will be announced later.

BIS DEVELOPMENT PROGRAMME

WILL YOU HELP US REACH OUR £25,000 TARGET?

A MAJOR RE-DEVELOPMENT of the Bessborough Gardens area of London in which the Society's headquarters are located compels us to obtain new premises. We have therefore launched an urgent Appeal to raise £25,000 as a downpayment on alternative office accommodation.

The Appeal is linked with our long-term aims to develop the Society in several important directions:

- **TO EXTEND EDUCATION IN SPACE RESEARCH AND TECHNOLOGY TO EMBRACE A WIDER COMMUNITY;**
- **TO EMPHASISE THE RAPIDLY INCREASING SOCIAL AND ECONOMIC BENEFITS OF SPACE APPLICATIONS;**
- **TO EXPAND FORWARD-LOOKING STUDIES IN ASTRONAUTICS ON AN INTERNATIONAL BASIS;**
- **TO INCREASE OUR MEMBERSHIP AT HOME AND ABROAD.**

EXECUTIVE SECRETARY
BRITISH INTERPLANETARY SOCIETY
12 Bessborough Gardens, London SW1V 2JJ.

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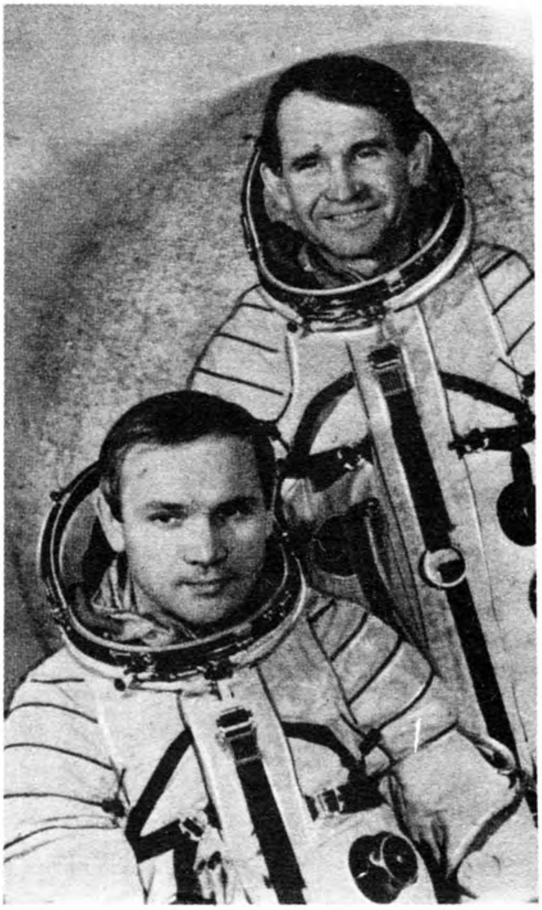
SPACEFLIGHT

88905 Космические полеты № Т-4
(спейсфлайт)
По подписке 1978 г.



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Assistant Editor:
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COVER

HIGHWAY TO SPACE. On 22 January Progress 1, an unmanned automatic ferry docked with the Salyut 6/Soyuz 27 space station watched by cosmonauts Georgi Grechko and Yuri Romanenko from inside Salyut 6. Progress 1 brought replenishment fuel, equipment and other supplies from Earth. Earlier that month Soyuz 27 cosmonauts Vladimir Dzhanibekov and Oleg Makarov had successfully docked with the orbital laboratory for five days, bringing mail, foodstuffs and scientific equipment, using the second docking port at the rear of the station. Our pictures show some of the preparations for the multiple docking. *Top left,* Romanenko and Grechko discuss their flight training programme alongside the Salyut 6 replica. Note the handholds fitted to the outside of the forward docking compartment to assist extra-vehicular activity which showed that the port was undamaged after the abortive Soyuz 25 docking mission last October. *Below*, Romanenko and Grechko familiarise themselves with the control console in the Salyut 6 trainer at the Gagarin Cosmonauts' Training Centre. *Right,* Dhzanibekov and Makarov who returned to Earth in Soyuz 26 on 16 January. The complex docking exercise recalls the words of Leonid Brezhnev: "Soviet science considers the creation of orbital stations with changing crews as the highway of man into space."

Novosti Press Agency

Cover design: David Holmes

SPACEFLIGHT

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MILESTONES

January

13 NASA announces that India plans to build a Landsat ground station designed to receive data directly from NASA's Earth resources satellites under a recently concluded agreement between the United States and India. The station, to be built and operated by the Indian National Remote Sensing Agency (NRSA) at Hyderabad in the south central Indian state of Andhra Pradesh, will be capable of receiving, processing and disseminating data covering all India and much of the surrounding region. *[Four Landsat ground stations are already in operation outside the United States: at Prince Albert, Saskatchewan and Shoe Cove, Newfoundland, Canada; Cuiaba, Brazil; and Fucino, Italy. Iran will begin receiving Landsat data from facilities near Tehran later this year. Ed.].*

14 Cosmonauts aboard Salyut 6 carry out "Resonance" experiment by jumping at intervals on their closed-belt running track, thus imparting vibrations to the whole complex; instruments installed at various points registered damping of the vibrations.

15 Cosmonauts study methods of controlling complex space system including orientation and stabilisation of whole complex. French 'Cytos' experiment is completed and biological specimens transferred to descent module of Soyuz 26.

15 Vladimir Dzanbekov and Oleg Makarov prepare to leave Salyut 6. They take apart the individually tailored supports of the seating arrangement of the Soyuz 27 ferry and re-assemble them in Soyuz 26. They also transfer their full pressure suits and personal belongings, pack film, papers and biological specimens they wish to ferry back to Earth. *Novosti* states that total length of Soyuz 26/Salyut 6/Soyuz 27 is 30 m (98.4 ft.), volume greater than 100 m^3 (3,531 ft^3) and weight exceeds 32 metric tons.

16 Re-entry module of Soyuz 26 soft-lands 310 km (192 miles) west of Tselinograd, Kazakhstan, at 15.30 hr. (Moscow time). Cosmonauts Dzanibekov and Makarov in good health. *[Several micro-organism containers (part of French 'Cytos' experiment) were later returned to National Space Research Centre in Toulouse. Ed.].*

16 NASA announces selection of 35 pilot-astronauts and mission specialists, six of whom are women aged between 26 and 35 qualified in medicine or the sciences, to meet the needs of the Space Shuttle programme. They join 27 existing astronauts.

16 New teleprinter 'hot line' linking the Kremlin and the White House by American Intelsat and Molniya communications satellites is officially inaugurated. Revealed that cable link installed in 1963 has been accidentally cut on three occasions.

18 Cosmonauts in the Salyut 6/Soyuz 27 space station begin 'Raduga' experiment to photograph the Earth using MKF-6M camera developed jointly by Soviet and East German specialists and made by Carl Zeiss Jena, East Germany. Camera is a modified version of the "multi-zonal" instrument flown on Soyuz 22. One tenth of photographic session devoted to "scientific purposes", remainder to surveying natural resources. Each frame covers area of about 165 x 220 km.

В журнале не печатается ряд страниц.

THE SOUNDS OF EARTH

Last year two Voyager spacecraft were launched on 'gravity assist' missions to explore the giant outer planets during which they will achieve velocities of some 17.2 km/sec allowing them to escape forever into the dark recesses of interstellar space. Voyager 1 should reach Jupiter in March 1979 and pass Saturn and its rings in November 1980. Voyager 2 should reach Jupiter in July 1979, Saturn in August 1981 and possibly Uranus in January 1986. Both will be considered to have left the Solar System when they cross the orbit of Pluto in 1989. It will take at least another 40,000 years before either craft comes anywhere near another star, passing it at a distance of about one light year. Other predicted approaches to stars – according to NASA – will occur in 147,000 and 555,000 years. In the chance that intelligent life-forms have emerged elsewhere in the Galaxy the Voyagers have been equipped with recorded messages which identify the origin and development of our species. The recordings, called 'Sounds of Earth,' were assembled by Professor Carl Sagan (BIS Fellow) of Cornell University, and a group of other distinguished scientists and educationalists.

Official insignia for the Voyager mission to the outer planets and the infinite spaces beyond was based on a design submitted by August L. Klerks, an employee of NASA's Jet Propulsion Laboratory which manages the Voyager project.

National Aeronautics and Space Administration

Introduction

The messages recorded on 12 in (30.5 cm) copper discs were designed to enable possible extraterristrial civilisations, who might intercept the spacecraft millions of years hence, to put together some picture of 20th century Earth and its inhabitants. They contain greetings and samples of music from different cultures and eras the natural sounds of surf, wind and thunder – and birds, whales and other animals.

The recordings also contain electronic information that an advanced technological civilisation could convert into diagrams, pictures and printed words, including messages from President Carter and U.N. Secretary-General Kurt Waldheim.

The idea of the record was formulated by Carl Sagan and the repertoire was selected by an advisory committee of prominent scientists, musicians and others.

"Because space is very empty, there is essentially no chance that Voyager will enter the planetary system of another star," said Sagan. "The spacecraft will be encountered and the record played only if there are advanced spacefaring civilisations in interstellar space."

"But, as the beautiful messages from President Carter and Secretary-General Waldheim indicate," he added, "the launching of this 'bottle' into the cosmic ocean says something very hopeful about life on *this* planet."

The Voyager Message

A disc recording was chosen because it can carry much more information in the same space than, for example, the Pioneer plaques. In addition, 1977 marked the 100th anniversary of the invention of the phonograph record by Thomas Alva Edison.

Each message disc is fitted into an aluminium protective jacket. It contains, in scientific language, information on how the record is to be played, using the cartridge and needle provided.

The record begins with 115 photographs and diagrams in analog form, depicting mathematics, chemistry, geology, and biology of the Earth, photographs of human beings of many countries, and some hint of the richness of our civilisation. Included are schematics about the Solar System, its dimensions and location in the Milky Way Galaxy, descriptions of DNA and human chromosomes, photographs of Earth, the

[Continued on page 126

This Voyager spacecraft was constructed by the United States of America. We are a community of 240 million human beings among the more than 4 billion who inhabit the planet Earth. We human beings are still divided into nation states, but these states are rapidly becoming a single global civilization.

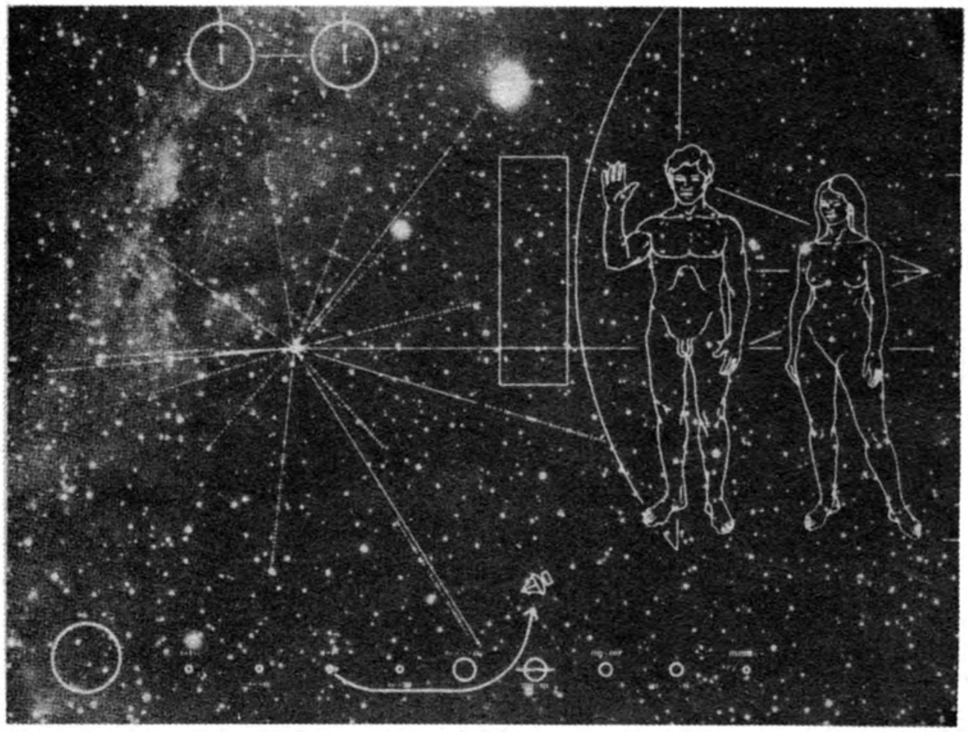
We cast this message into the cosmos. It is likely to survive a billion years into our future, when our civilization is profoundly altered and the surface of the Earth may be vastly changed. Of the 200 billion stars in the Milky Way galaxy, some -- perhaps many -- may have inhabited planets and spacefaring civilizations. If one such civilization intercepts Voyager and can understand these recorded contents, here is our message:

> This is a present from a small distant world, a token of our sounds, our science, our images, our music, our thoughts and our feelings. We are attempting to survive our time so we may live into yours. We hope someday, having solved the problems we face, to join a community of galactic civilizations. This record represents our hope and our determination, and our good will in a vast and awesome universe.

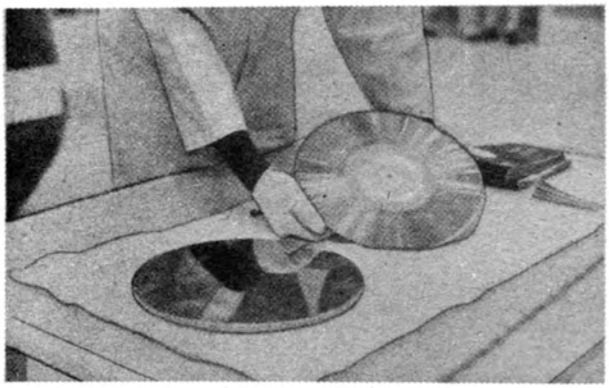
Jimmy Carter

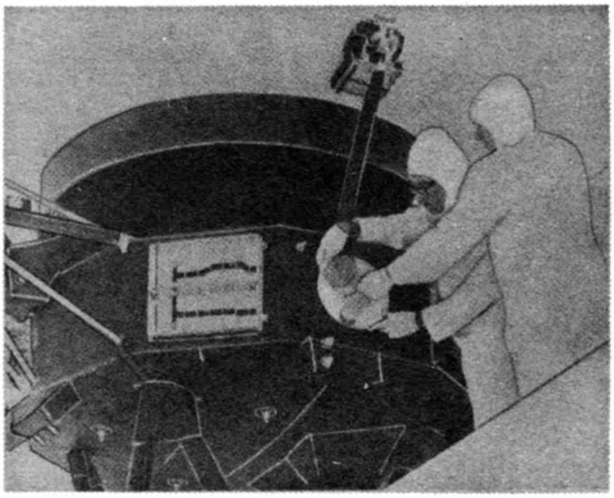
President of the United States of America

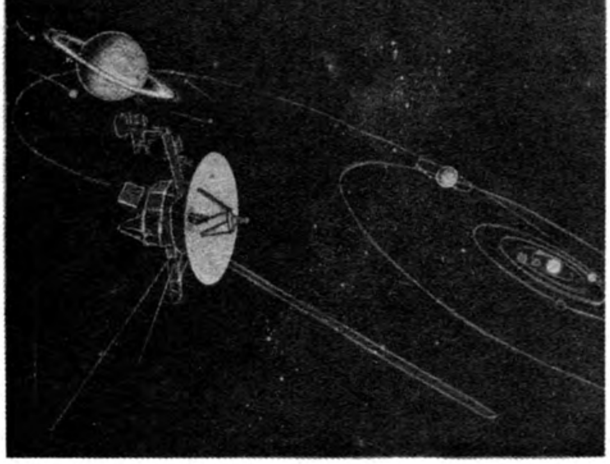
Original of the CETI message recorded by President Jimmy Carter and placed aboard the Voyager spacecraft.



First CETI messages took the form of metal plaques sent into space aboard the space probes Pioneers 10 and 11. They were designed by Drs. Carl Sagan and Frank Drake and drawn by Linda Sagan, who is an artist and film maker. From them an intelligent extra-terrestrial might deduce something about human beings, their location in the Galaxy and the time the spacecraft has been travelling (based on the regular decrease in the frequencies of pulsars) [1].







Above, placing the message disc aboard a Voyager spacecraft.

Above, left, 'Sounds of Earth' disc recording.

Left, VOYAGER TRAJECTORY. On their way out of the Solar System Jupiter's gravity will slingshot the Voyagers toward the ringed planet Saturn. They are expected to leave the Solar System in 1989.

All photos Jet Propulsion Laboratory

Voyager Message of UN Secretary General

"As the Secretary General of the United Nations, an organisation of 147 member states who represent almost all of the human inhabitants of the planet Earth, I send greetings on behalf of the people of our planet. We step out of our Solar System into the Universe seeking only peace and friendship, to teach if we are called upon, to be taught if we are fortunate. We know full well that our planet and all its inhabitants are but a small part of the immense universe that surrounds us and it is with humility and hope that we take this step."

Kurt Waldheim

- Pictures (In Electronic Form)
- President Carter's Message (In Electronic Form)
- Congressional List
- UN Secretary General Waldheim's Message (Spoken)
- Greetings in 60 Languages
- Sounds of Earth
- Music

Languages Heard on Voyager Record (Not in Sequential Order)

Sumerian	Spanish	Turkish	Swedish
Akkadian	Indonesian	Welsh	Ukrainian
Hittite	Kechua	Italian	Persian
Hebrew	Dutch	Nguni	Serbian
Aramaic	German	Sotho	Luganada
English	Bengali	Wu	Amoy (Min dialect)
Portuguese	Urdu	Korean	Marathi
Cantonese	Hindi	Armenian	Kannada
Russian	Vietnamese	Polish	Telugu
Thai	Sinhalese	Netali	Oriva
Arabic	Greek	Mandarin	Hungarian
Roumanian	Latin	Gujorati	Czech
French	Japanese	Ila (Zambia)	Rajasthani
Burmese	Punjabi	Nyanja	

Sounds of Earth on Voyager (In Order of Sequence)

Whales	Footsteps and Heartbeats	Horse and Cart
Planets (Music)		Horse and Carriage
Volcanoes	Laughter	Train Whistle
Mud Pots	Fire	Tractor
Rain	Tools	Truck
Surf	Dogs, domestic	Auto gears
Crickets, Frogs	Herding sheep	Jet
Birds	Blacksmith shop	Lift-off Saturn 5 Rocket
Hyena	Sawing	
Elephant	Riveter	Kiss
Chimpanzee	Morse Code	Baby
Wild Dog	Ships	Life signs - - EEG, EKG
		Pulsar

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66. Elephant, Peter Kunstadter.
67. Old man with beard and glasses (Turkey), Jonathon Blair.
68. Old man with dog and flowers, Bruce Baumann.
69. Mountain climber, Gaston Rebuffat.
70. Cathy Rigby, Philip Leonian.
71. Sprinters (Valeri Borzov of the U.S.S.R. in lead), *The History of the Olympics.*
72. Schoolroom, UN.
73. Children with globe.
74. Cotton harvest, Howell Walker.
75. Grape picker, David Moore.

76. Supermarket, H. Eckelmann.
77. Underwater scene with diver and fish, Jerry Greenberg.
78. Fishing boat with nets, UN.
79. Cooking fish, *Cooking of Spain and Portugal.*
80. Chinese dinner part, Michael Rougier.
81. Demonstration of licking, eating and drinking, H. Eckelmann.
82. Great Wall of China, H. Edward Kim.
83. House construction (African), UN.
84. Construction scene (Amish country), William Albert Allard.
85. House (Africa), UN.
86. House (New England), Robert Sisson.
87. Modern house (Cloudcroft, New Mexico), Dr. Frank Drake.
88. House interior with artist and fire, Jim Amos.
89. Taj Mahal, David Carroll.
90. English city (Oxford), *C.S. Lewis, Images of His World.*
91. Boston, Ted Spiegel.
92. UN Building Day, UN.
93. UN Building Night, UN.
94. Sydney Opera House, Mike Long.
95. Artisan with drill, Frank Hewlett.
96. Factory interior, Fred Ward.
97. Museum, David Cupp.
98. X-ray of hand, H Eckelmann.
99. Woman with microscope, UN.
100. Street scene, Asia (Pakistan), UN.
101. Rush hour traffic, India, UN.
102. Modern highway (Ithaca), H. Eckelmann.
103. Golden Gate Bridge, Ansal Adams.
104. Train, Gordon Gahan.
105. Airplane in flight, Dr. Frank Drake.
106. Airport (Toronto), George Hunter.
107. Antarctic Expedition, *Great Adventures with the National Geographic.*
108. Radio telescope (Westerbork, Netherlands), James Blair.
109. Radio telescope (Arecibo), H. Eckelmann.
110. Page of book (Newton, *System of the World).*
111. Astronaut in space, NASA.
112. Titan Centaur Launch, NASA.
113. Sunset with birds, David Harvey.
114. String Quartet (Quartetto Italiano), Phillips Recordings.
115. Violin with music score (Cavotina).

Music on Voyager Phonograph Record (In Sequential Order)

1. Bach Brandenberg Concerto Number Two, First Movement, Karl Richter conducting the Munich Bach Orchestra.
2. "Kinds of Flowers" Javanese Court Gamelan, recorded in Java by Robert Brown, Nonesuch Explorer Record.
3. Senegalese Percussion, recorded by Charles Duvelle.
4. Pygmy girls initiation song, recorded by Colin Turnbull (Zaire).
5. Australian Horn and Totem song. Recorded in Australia by Sandra LeBrun Holmes. Barnumbirr-Morning Star Record.
6. "El Cascabel" Lorenzo Barcelata. The Mariachi Mexico.
7. "Johnny B. Goode", Chuck Berry.
8. New Guinea Men's House, recorded by Robert MacLennan.
9. "Depicting the Cranes in Their Nest" recorded by Coro Yamaguchi (Shakubachi).
10. Bach Partita Number Three for violin. Gavotte et Rondeaus, Arthur Grumiaux, violin.
11. Mozart Magic Flute, Queen of the Night (Aria Number 14) Edda Moser, soprano.
12. Chakrulo. Georgian (USSR) folk chorus.
13. Peruvian Pan Pipes performed by Jose Maria Arguedas.
14. Melancholy Blues performed by Louis Armstrong, Columbia Records.
15. Azerbaijan Two Flutes. Recorded by Radio Moscow.
16. Stravinsky, Rite of Spring, Conclusion. Igor Stravinsky conducting the Columbia Symphony Orchestra.
17. Bach Prelude and Fugue, Number One in C Major from the Well Tempered Clavier, Book Two, Glenn Gould, piano.
18. Beethoven's Fifth Symphony, First Movement. Otto Klem Klemperer conducting. Angel Recording.
19. Bulgarian Shepherdess Song. "Izlel Delyo hajdutin," sung by Valya Balkanska.
20. Navajo Indian Night Chant. Recorded by Williard Rhodes.
21. The Fairie Round from Pavans, Galliards, Almains. Recorded by David Munrow.
22. Melanesian Pan Pipes. From the collection of the Solomon Islands Broadcasting Service.
23. Peruvian Woman's Wedding Song. Recorded in Peru by John Cohen.
24. "Flowing Streams" - - Chinese Ch'in music. Performed by Kuan-P'ing-Hu.
25. "Jaat Kahan Ho" - - Indian Raga. Performed by Surshri Kesar Bai Kerkar.
26. "Dark Was the Night" performed by Blind Willie Johnson.
27. Beethoven String Quartet Number 13 "Cavatina", performed by Budapest String Quartet.

Continued from page 123]

Voyager launch vehicle, a large radio telescope and human beings in various settings and endeavours.

That information is followed by spoken greetings in approximately 60 human languages, including a spoken message by Kurt Waldheim, Secretary General of the United Nations.

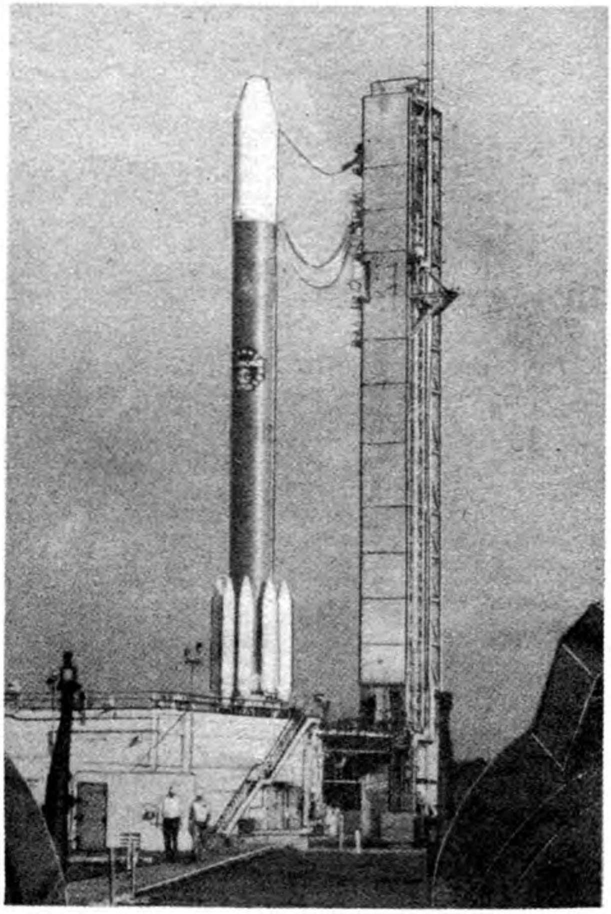
Next comes a sound essay on the evolution of the planet Earth, including sounds of weather and surf, the Earth before life, life before humankind appeared and, finally the development of human civilisation.

The musical selections, which run to almost 90 minutes playing time, are representative of the cultural diversity of Earth, of many times and places, and include both Eastern and Western classical music and a variety of ethnic music. Included is music from Senegal, Australia, Peru, Bulgaria, and Azerbaijan, as well as jazz and rock and roll. In the classical repertoire are compositions by Bach, Beethoven, Mozart, and Stravinsky, as well as Javanese Gamelan, Indian Raga, Japanese Skakuhachi, and Chinese Ch'in music. The entire $16\frac{2}{3}$ rpm record runs nearly two hours.

Because of the aluminium cover and the emptiness of interstellar space, the record is likely to survive more than a thousand million years. Thus it represents not only a message into space but also a message into time.

METEOSAT: EUROPE'S GEOSTATIONARY WEATHER SATELLITE

Meteosat was built for the European Space Agency by the COSMOS consortium of aerospace companies. It is to be one of a group of five satellites giving worldwide meteorological coverage; the other four come from the USA (2), Japan and the USSR. They are being placed in geostationary orbits equidistant from each other above the equator. Meteosat's position is 0° latitude, 0° longitude, at an altitude of 35,880 km. Its field of view includes the eastern part of South America, the whole of Africa, most of the Middle East and Europe south of 55° latitude, including England and Ireland. The satellite takes white light and infrared pictures of the Earth's surface every 30 minutes, scanning line by line as it rotates at 100 r.p.m. Line-to-line shift is achieved by tilting the telescope. The picture obtained can be used direct by the ground station. However, for more precise definition and to render the data compatible with international APT (Automatic Picture Transmission) and WEFAX (Weather Facsimile) standards the picture can be processed on the ground and transmitted back to the satellite for retransmission to other stations.
The infrared picture provides information on surface and cloud temperatures and hence cloud height, while the visible light picture shows cloud formation and enables wind velocity to be calculated with an accuracy of 3 metres per second by noting cloud movements. In addition, information collected from platforms, buoys, Earth stations and satellites in low polar orbits can be retransmitted by Meteosat to any user, including sea-borne vessels, *via* WEFAX.
The five satellites will provide meteorologists with a continuoulsy changing picture of world weather, enabling dangerous phenomena such as typhoons, hurricanes and torrential rain to be plotted and their paths predicted in time to warn the authorities in the endangered areas. Less dramatic weather conditions also will be predicted more accurately to the benefit of farmers, fishermen and small boat sailors.



Meteosat awaits lift-off from Cape Canaveral in the nose of a Delta 2914. The launch was eventually made on 22 November 1977. Final stationing in geostationary orbit above the Gulf of Guinea was achieved on 7 December.

National Aeronautics and Space Administration

Introduction

The limited amount of satellite data which European meteorologists received before Meteosat came from spacecraft really designed to provide information for one or two day forecasts of weather conditions in the United States. Only a *global* system of carefully positioned satellites in geostationary orbit can make continuous observation of all the Earth's surface and cloud cover necessary to produce, for Europe or any other region, accurate weather forecasts for weeks rather than days. Climatic conditions in one part of the world can affect the weather many thousands of kilometres away.

Meteosat, poised in orbit some 35,880 km (22,300 miles) above the Gulf of Guinea at longitude 0°, is expected to provide total and continuous coverage of Europe, the Near East and Africa for at least three years.

Launched from Cape Canaveral by a Delta 2914 rocket on 22 November 1977 (*Spaceflight*, February 1977, p. 48), the satellite is designed to enable the European meteorological services to improve the precision of their long-range weather forecasts. With its coverage area extending far beyond the geographical limits of the countries participating in the programme, Meteosat also will constitute Europe's contribution to two programmes set up by the World Meteorological Organisation (WMO):

- *the World Weather Watch, a continuous programme;*
- *the Global Atmospheric Research Programme (GARP), an experimental programme in which the first experiment is at present planned to take place from the end of 1978 to the end of 1979.*

Meteosat will thus be integrated in a world network of five geostationary satellites comprising, in addition to the European satellite, two American satellites (GEOS), one Soviet satellite (GOMS),* and a Japanese satellite (GMS), located symmetrically in orbit above the equator.

Coverage Area

Meteosat is located above the Atlantic Ocean at 0° longitude (i.e. in the equatorial plane) and monitors continuously the cloud masses and the surface of the Earth visible from the geostationary orbit. It will thus provide a large number of meteorological data affecting Europe, the Middle-East and the whole of Africa. From its position, the satellite will observe continuously the same part of the terrestrial globe, noting any variation from one observation to the next, which are signs of various meteorological events that are

* *The Soviet Meteorological Satellite (GOMS) has been delayed.*

normally so difficult to observe in view of the low density of weather stations, particularly in the sea and desert areas.

Objectives and Missions

Meteosat has been designed to carry out three main missions:

1. *Image production.* This mission involves the scanning every half hour, in three spectral bands, of the Earth's surface and cloud masses located within the satellite's coverage area. The images thus produced will provide a certain amount of information on:
   - cloud cover and in particular cloud-top height and cloud motion;
   - sea surface temperatures;
   - wind velocity;
   - water vapour distribution in the upper layers of the troposphere; and
   - radiation balance.
2. *Dissemination.* This mission involves the dissemination of cloud-cover images or of meteorological data derived from those images. The aim is to let the largest number of users to have access to the data produced either by Meteosat or by other means (e.g. data collection platforms, the American GEOS satellite).
3. *Data collection.* In addition to image production, Meteosat will collect local information gathered either by automatic (or semi-automatic) stations, called data collection platforms, or possibly by a satellite in a low polar orbit. The aim of this latter mission is to gather information obtained locally, which will complete the images produced by Meteosat.

The Meteosat Satellite

The Meteosat programme is based on the setting up of a complex system whose main components are a geostationary satellite, tracking facilities, the data processing centre, the user stations, and the data collection platforms.

Meteosat is a geostationary satellite, spin-stabilised at 100 rpm, with its spin axis perpendicular to the orbital plane. The spacecraft is of cylindrical shape, 3.20 m high with a diameter of 2.10 m. Its mass at launch is nearly 700 kg, including the apogee motor (345 kg) and the securing devices. The satellite is of a relatively simple design, which involves a double structure:

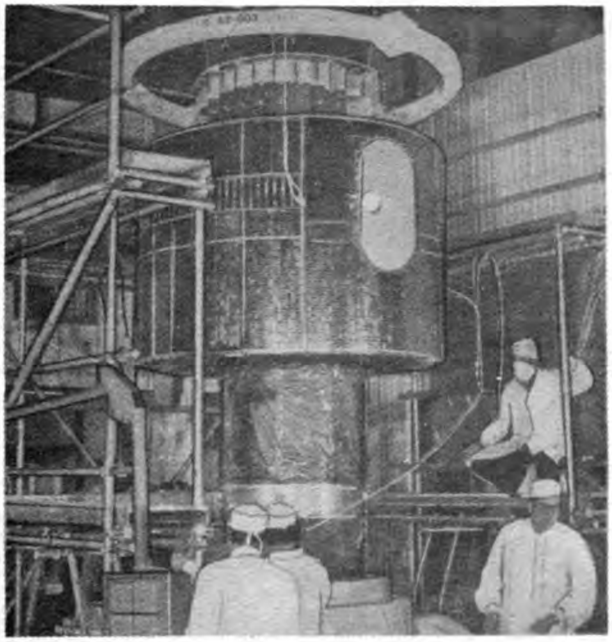
- a primary structure which bears, in addition to the mechanical loads, a main platform carrying the support equipment and an upper platform bearing the antennae and most of the communications equipment;
- a secondary structure carrying the six solar panels and the heat shields.

The payload consists of a high resolution radiometer and a data transmission system.

The radiometer is an electro-optical instrument whose main element is a 40-cm-aperture Ritchey Chrétien telescope. In can produce simultaneously, in 25 minutes, two images of the Earth, one in the visible region of the spectrum and the other in the thermal infrared. In addition it has a water-vapour channel in the infrared.

The data transmission and information relay system comprises a transponder working with an antenna system. It operates in the L, S and UHF bands.

Meteosat and the apogee boost motor on the 'shaker' in Toulouse.



Tracking and Data-Processing

In order to carry out its meteorological mission, the satellite will work with the following ground facilities:

- The Data Acquisition, Telecommand and Tracking Station (DATTS) – located at Michelstadt near the European Space Operations Centre (ESOC) at Darmstadt in the Federal Republic of Germany – is concerned with the acquisition of the radiometric, attitude and housekeeping data of the satellite and of the messages from the platforms. Secondly, it transmits the meteorological data or images and the telecommands. Lastly, it carries out the ranging measurements for the location of the satellite in its orbit, working in association with a land-based transponder (LBT) located at Kourou in French Guiana.
- The Meteosat Operations Control Centre (MOCC) is entrusted with the operational management of the whole system. It monitors the performance and operation of the satellite and all associated elements, including the orbit and attitude restitution calculations.
- The Data Referencing and Conditioning Centre (DRCC) is responsible mainly for the processing leading to the formatting of images and their subsequent exploitation.
- The Meteorological Information Extraction Centre (MIEC), working on the basis of the processed radiometric data, extracts the specifically meteorological information such as wind fields, sea temperature charts, cloud system analyses, radiation balances.

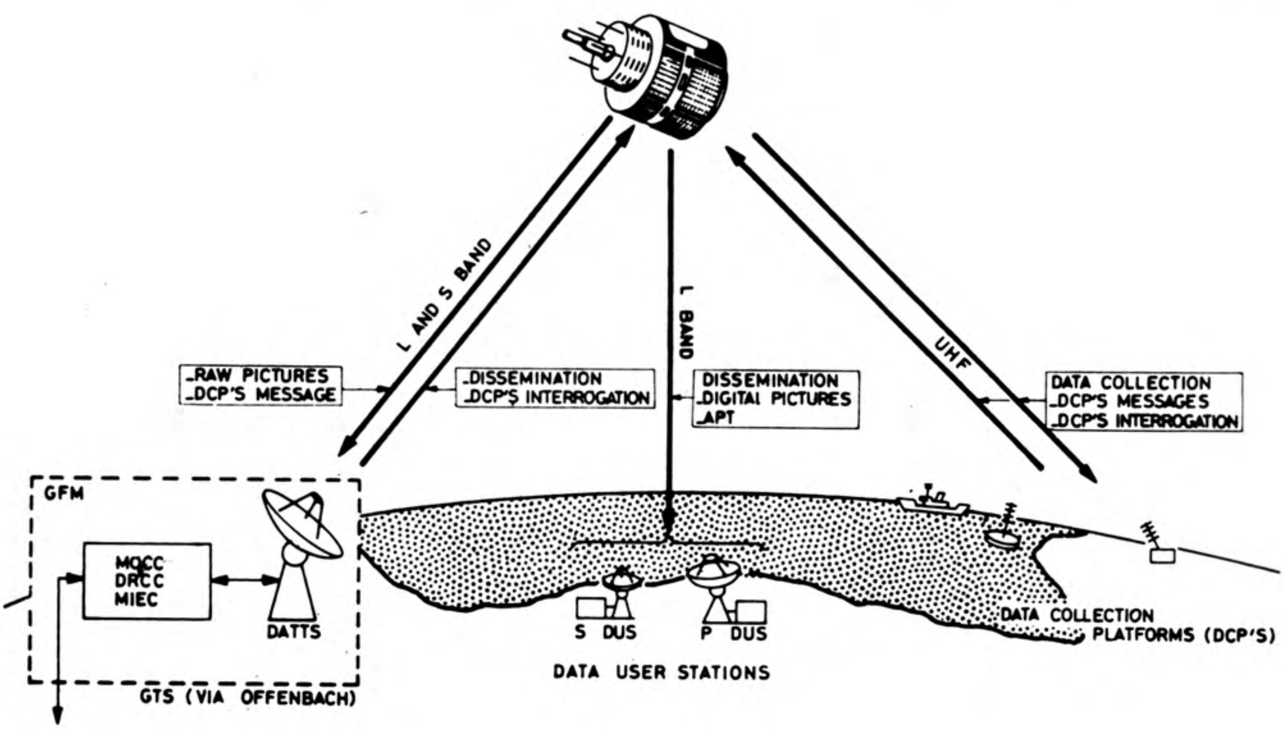
These last three centres, MOCC, DRCC and MIEC, are in fact utilisation consoles connected with a computing unit called Meteosat ground computer system (MGCS), which is located at ESOC and linked with the DATTS by a high-speed terrestrial circuit.

The User Stations

In addition to the facilities developed and set up by ESA,

First picture of the Earth-globe taken in the visible region of the spectrum by Meteosat on 9 December 1977 shortly after mid-day. *Below,* Meteosat: Data collection and dissemination.

ESA



the Meteosat system comprises stations that receive the images and the processed data in digital and analog forms. These stations will be set up at the request of the users.

The primary data-user stations (PDUS) are designed for the reception and display of high resolution images and digital data in APT format. They are equipped with antennae about 4 m in diameter.

The secondary data-user stations (SDUS) receive images and analog data in APT format. They are VFH-APT stations adapted for "S" band reception by the addition of specific equipment. The receiving antenna has a diameter of 2.50 m.

The Data Collection Platforms (DCP)

These are electronic units comprising an antenna, external sensors, and a transmitter. These automatic or semi-automatic platforms carry out local environment measurements and transmit them to the central Meteosat station *via* the satellite.

They can be installed in extremely varied environments and on various forms of support, namely on the ground, on buoys or aboard ships. They will be supplied and set up at the request of the users.

Some of these platforms, called international platforms, can operate throughout the area covered by the various satellites set up for the GARP experiment. They will be operated in accordance with an established procedure and programme recognised internationally by the Geostationary Satellite Coordinating Committee (GSCC).

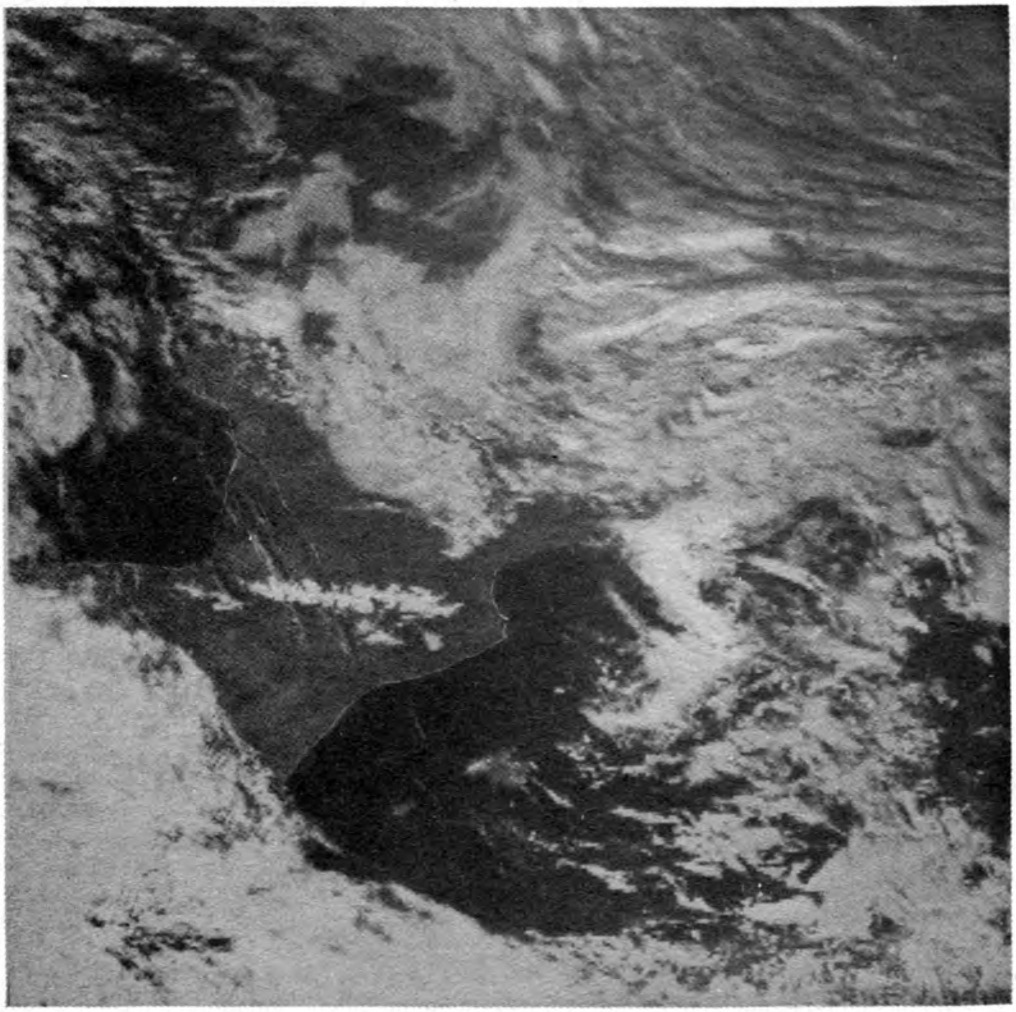
The regional platforms will operate with a single satellite.

Imaging

From its geostationary position, the satellite observes the cloud cover in the visible and infrared regions by means of a radiometer which in twenty-five minutes will produce two images (the first one in the visible region, the second in the thermal infrared or water-vapour infrared region) with a resolution of 2.5 km in the visible and 5 km in the infrared. The infrared images are composed of 2,500 lines consisting of 2,500 image points each, and the visible images are composed of 5,000 lines with 5,000 points each. The line scanning is done by the rotation of the satellite, which spins at a rate of 100 rpm. The passage from one line to the next is done by the step-by-step movement of the telescope, synchronised with the satellite's rotation period.

The images received on the ground in digital or analog form are of a sufficiently high quality for immediate use. But for a more precise definition and for the data to be compatible with the international APT (Automatic Picture Transmission) or WEFAX (Weather Fac Simile) standards, the raw image is processed on the ground and then re-transmitted to the satellite for dissemination to the weather stations.

The processing consists in a series of operations designed to rectify errors and distortions due to movements of the satellite with respect to the Earth, to format the pictures, to relate the meteorological phenomena to the observed geographical areas and to extract the meteorological data. The pictures are transmitted to the users on different frequencies, depending on the nature (digital or analog) of the document and its format. However, this frequency will

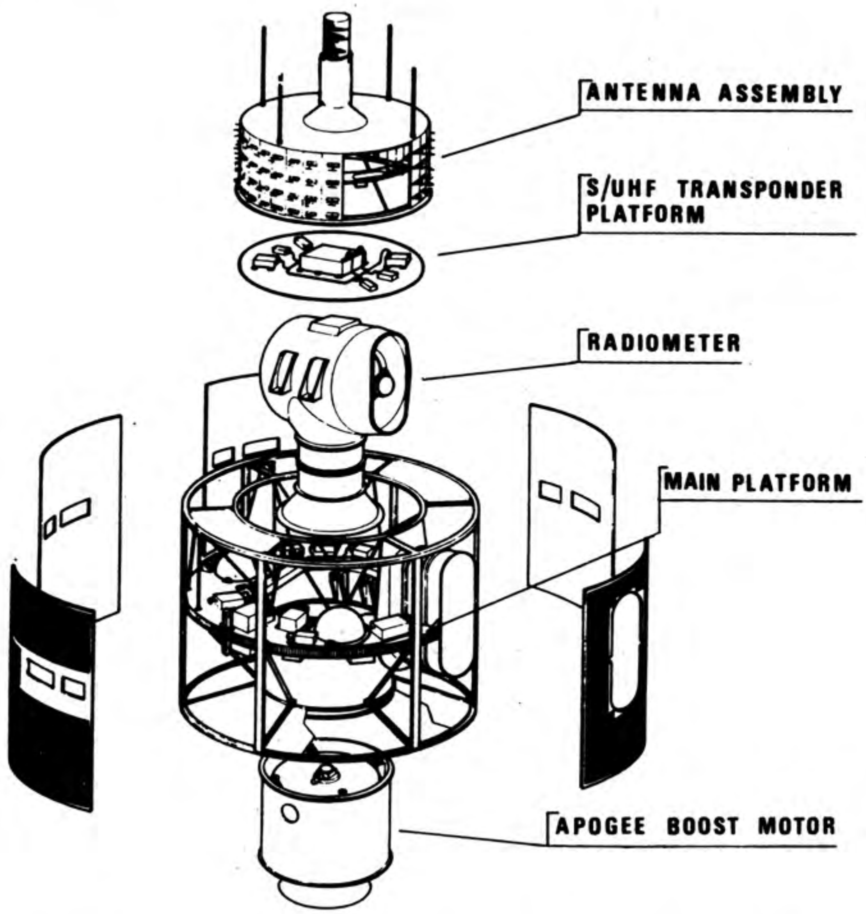


Picture of Earth's surface and cloud cover taken in the visible region of the spectrum by Meteosat on 9 December shortly after midday. Left of centre can be seen part of Spain and France; top left, part of England.

ESA

Meteosat: exploded view of satellite.

Marconi Space and Defence Systems Limited



be relatively high and the maximum interval between the transmission of two documents to one station can be estimated at not more than three hours.

The images will be put to a great variety of uses. Exploitation of the infrared images will make it possible to determine, on the one hand, the Earth-surface and cloud temperatures with a precision of 1°C (from which the cloud height can be deduced), and on the other hand wind speed (with a precision of 3 m/s), particularly in the tropical areas, from the movement of small clouds used as "tracers."

Used as a relay station, Meteosat will transmit to the users the raw and processed images, certain images produced by the American GEOS satellite and received by the Lannion station, and messages from the data collection platforms. Meteorological data extracted from the images (wind field, radiation balances, temperatures, etc.) will be forwarded by the data transmission network of the WMO (GTS), which will be connected to the Darmstadt data processing centre through the Regional Telecommunications Headquarters (RTH) at Offenbach, near Darmstadt.

Meteosat and Meteorological Research

Throughout its operational life, Meteosat will transmit a large amount of information that will make it possible to improve knowledge of meteorological phenomena and to make forecasts with greater precision.

In the first instance, the meteorological images will lead to a better understanding of the overall mechanisms of the movements of the atmosphere. The main contribution in this area will be observation of inter-hemisphere air masses and of the energy fluxes linked to the various perturbations affecting the inter-tropical convergence zone.

Study of the atmospheric circulation at medium latitudes (such as Southern Europe) will also consitute one of the interesting applications of the mission, particularly at the time of seasonal transition when interactions generally occur between the tropical air masses and those in the temperate regions.

Thanks to its capability of sampling air masses and its frequency of observation, Meteosat should be of substantial help in the understanding of phenomena that govern the formation of isolated air masses under the influence of their atmospheric environment. Lastly, in view of the performance of the radiometer, notably in the infrared, it is hoped to collect important information that will serve in the study of energy transfer and particularly of the radiation balances.

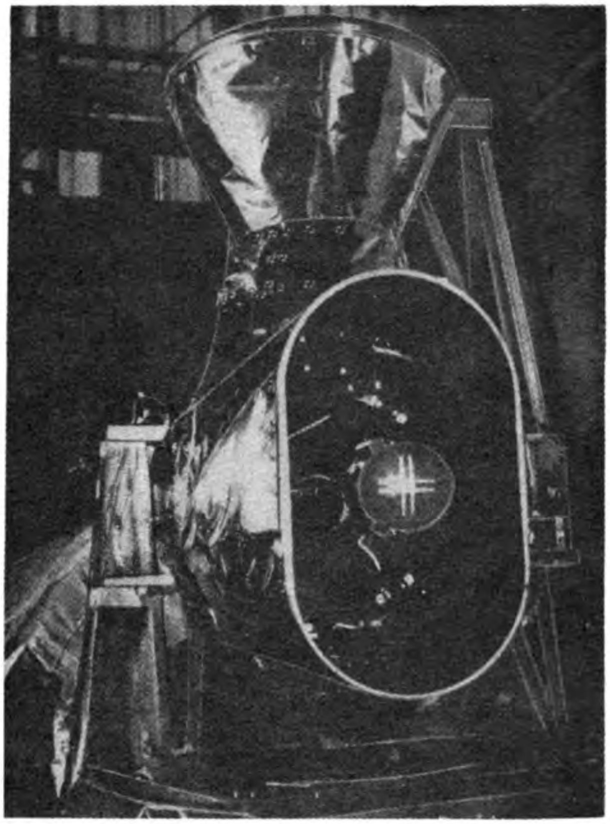
Apart from these purely scientific objectives, the information transmitted by the satellite will be of immediate use in helping the weather stations in the rapid detection of hurricanes and violent storms and thus to issue short-range forecasts and warnings to save human lives and limit material damage.

The Satellite

Meteosat is designed around a twofold structure. A primary structure bears the mechanical loads. It consists of a central tube providing the connection with the launch vehicle and the jettisonable apogee motor, a main platform accommodating essentially support equipment, and an upper platform bearing the antennae and most of the communications equipment.

The six solar panels and the heat shields are supported by an ultra-light secondary structure.

Thermal control is essentially passive. It uses the principle of heat exchanges by radiation and conduction. The system



The Meteosat radiometer during vibration testing in Toulouse.

European Space Agency

is designed to dissipate, in the form of heat, energy of about 300 W from electrical sources, simultaneoulsy with the external heat exchange due to the coldness of space and to insolation. Coatings, ranging from black paints to "SSM" solar reflectors, together with the superinsulations and special heat shields, form the major elements of thermal control.

Electrical Power Supply

The role of the power-conditioning sub-system for electrical power supply is to provide each item of equipment with the energy required. During a period of insolation, the main bus is fed from the 6-panel solar cell array. The excess power is dissipated in the form of heat in resistances mounted on the upper part of the central body. In a period of eclipse, the power is supplied by a nickel-cadmium battery with a capacity of 7 ampere-hours.

A control unit stabilises the main bus at 28 V(± 1%).

A series of six separate converters is associated with each of the other main sub-systems in order to provide them with the required voltages.

Stabilisation and Attitude Measurements

Meteosat is spin-stabilised. The precision of this stabilisation requires a very sophisticated attitude-control system since it directly influences the sharpness of the image transmitted to Earth.

The attitude and orbit control system is a double-thrust-level hydrazine system. It consists mainly of three large spherical tanks for the storage of propellants and of two sets of three control thrusters (axial, radial and vernier-radial).

Stationing manoeuvres are effected either by continuous operation in the case of inclination corrections by axial

METEOSAT: TECHNICAL DATA

The satellite is 3.2 metres (10.4 ft.) high and 2.1 metres (6.825 ft.) in diameter. At launch it weighed 700 kg (1,540 lb.) and, after the Apogee Boost Motor had burned to place it in final orbit, 300 kg (660 lb.).

Power Supply:

28V d.c. stabilised to ± 1% in sunlight and in eclipse.
Battery is 7 ampere hour capacity, charged during sunlight phase of the satellite solar array.

Telecommunications:

S-Band Uplink 2.1 GHz.
S-Band Downlink 1.7 GHz.
UHF Uplink 402 MHz.
UHF Downlink 469 MHz.
S-Band Transmitter 8W. } Combined in S-Band
S-Band Receiver noise limit of 4.8 dB } UHF Transponder
UHF Transmitter 20W.
UHF Receiver Noise Limit 4.4 dB.

Telecommand Transmitters and Receivers

2 VHF Transmitters 6.5 Watts (6W r.f. in back up mode)
2 VHF Receivers with a sensitivity of -112 dBm, plus an on board Encoder. Modulation is PCM.

Antennae

S-Band directional antenna, electronically despun, gain 13 dB.
Consists of 128 dipoles arranged in 32 rows of 4 on a cylindrical structure.
S-Band back up antenna – gain 2.5 dB.
UHF antenna, gain 0 dB consisting of 4 halfwave dipoles.
VHF antennae. 4 monopoles at 90° spacing.

Telemetry

Input Capability	162 analogue channels.
	96 digital ON/OFF channels.
	57 serial digital channels.
Bit Rate	325 bits/second.
Output Capability	224 low-level ON/OFF channels.
	32 high-level ON/OFF channels.
	30 user lines.
	There is a deferred transmission capability.

Radiometer and image channel

Daylight wavelength	0.5 - 1.0μm.
Infrared	10.5 - 12.5μm.

Also water vapour absorption band at 5.7 to 7.1μm.
Synchronisation controlled by 5.3 MHz crystal oscillator.

Data

A/D conversion accuracy	6 bits per visible channel.
	8 bits per infrared channel.
A/D conversion on bit rate	2.67 megabits per second.
Data storage capacity	80 kilobits per line plus partial standby redundancy.
Transmission bit rate	Normal mode 167 kilobits/second.
Direct (No redundancy)	2.67 megabits/second.

Attitude and orbital control

Spin stabilised	rate of spin 100 r.p.m.
Spin axis precision	less than 0.3°
Attitude resolution	better than 0.1°
Propellant	Hydrazine stored in 3 spherical tanks.
Thrusters	2 groups each of radial, axial and vernier thrusters.

Nutation damping	Automatic following detection by accelerometers.
Fuel pressure	Maintained by nitrogen gas, monitored by a pressure transducer.
Sensors	Four Earth sensors. Four Sun sensors. Two accelerometers (also used in nutation damping).

thrusters, or in pulsed mode for correction in the orbital plane by radial thrusters. The vernier thrusters supplement the radial thrusters in providing opposite and equal spin moments without therefore affecting spin velocity. The change in spin velocity may be produced by continuous or pulsed operation of a single radial or vernier thruster, attitude changes being carried out by means of an axial or vernier thruster in pulsed mode.

The attitude and orbit control system is completed by a pair of fluid nutation dampers capable of keeping nutation below 2″.

The attitude measurement sub-system comprises a series of four Earth sensors, four Sun sensors, and two accelerometers acting as nutation sensors. The data from these sensors are transmitted to Earth after processing by the on-board electronics and are used to reconstitute the spacecraft attitude.

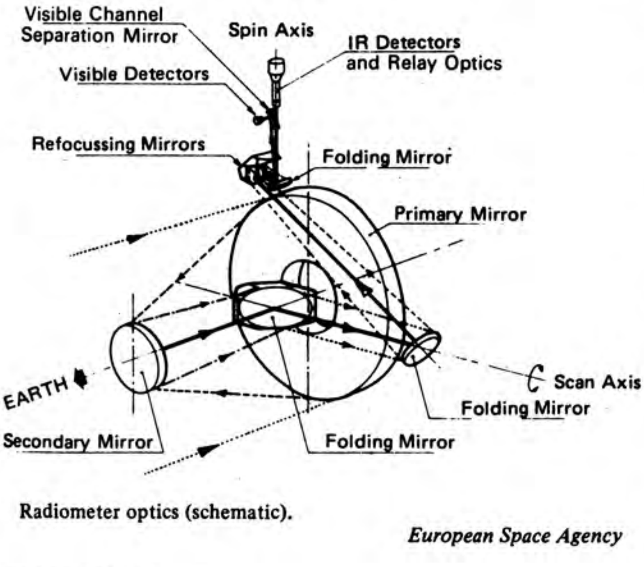
Radiometer and the Imaging System

The high-resolution radiometer, the Meteosat camera, is an electro-optical device which consists mainly of a Ritchey-Chrétien telescope with 40 cm aperture, scanning, focussing and calibration mechanisms, and electronic detection systems. The images are taken in visible light at wavelengths from 0.5 to 1μ and in infrared from 10.5 to 12.5μ. An additional channel is available in the water vapour absorption band of 5.7 to 7.1μ.

The synchronisation sub-system of the imaging system generates all the dating and control signals. This system, controlled by a quartz oscillator (5.3 MHz), is reset by a Sun (or Earth) sensor for each orbital revolution of the satellite. It synchronises the radiometer scanning, the despun antenna, and the transmission of data to Earth. It monitors and controls all the satellite imaging operations.

The analog data of the radiometer are converted into digital signals at high velocity by image-processing units.

A memory provides temporary storage so that data can be transmitted at a slower and continuous rate.



Radiometer optics (schematic).

European Space Agency

Main Telecommunications

The main telecommunications sub-system ensures the transmission to the Earth of the data produced by the imaging system and retransmission of the processed images to the various user stations, either in digital form for high-resolution images or in analog form campatible with the APT or WEFAX formats.

Interrogation of the automatic platforms, and acquisition and retransmission of their data also form part of the role of this sub-system, together with the ancillary telecommunications, telecommand and telemetry, effected in the S-band in geostationary position.

Links between the satellite and the ground stations operate in the S-band, except for those between the satellite and the data collection platforms which operate on UHF. These tasks are performed by an S-band/UHF repeater consisting mainly of an S-band receiver, an S-band transmitter, a UHF receiver and a UHF transmitter.

Antennae

A directional, electronically despun antenna (gain approximately 13 dB) is used for S-band transmissions. It consists of 128 dipoles arranged in 32 columns of four on a cylindrical structure. A switching matrix feeds in succession the appropriate five columns of dipoles facing the Earth.

S-band reception is ensured by a toroidal pattern antenna. Another antenna of the same type is available for stand-by transmission (gain 2.5 dB). Each antenna consists of a series of slots on a rectangular waveguide. They are placed side by side within a dielectric cylindrical housing. The UHF links are provided by another toroidal pattern antenna (gain approx. 0 dB). It consists of four half-wave dipoles produced by metallic films on a dielectric cylindrical structure.

Telemetry and Telecommand

The telemetry and telecommand sub-system provides the basic service link between the satellite and the Earth. It informs the Earth at any time about the behaviour of the satellite and carries all ground commands.

The sub-system has an on-board coder and two VHF transmitters, a decoder and two VHF receivers, and possesses on the ground the equipment needed for measuring the accuracy of stationing.

The VHF band is used for telemetry and telecommand during the stationing phase. On station, the telemetry and telecommand systems operate in the S-band in the normal mode. In standby mode the VHF band is used.

The VHF antenna comprises four monopoles fed by signals of equal amplitude in phase quadrature.

The UK Contribution

The British Company Marconi Space and Defence Systems Limited, a member of the GEC-Marconi Electronics group, was one of the principal companies involved in building the satellite, providing the attitude and orbital control system, the electrical ground support equipment and part of the communications package. The work was carried out at the company's sites in Portsmouth and Frimley. The attitude and orbit control hardware comprises reaction control equipment, the highly accurate attitude measurement system based on Sun and Earth sensors, and the attitude and orbit control electronics. The electronics unit processes the attitude sensor data for transmission to Earth and provides the drive signals to the thrusters. In addition to providing integration support MSDS sent a team to Cape Canaveral to ensure that the final fuelling and checkout of these systems was carried out correctly before the satellite was mated to its launch vehicle, Delta 2914.

The checkout of the whole spacecraft was carried out using well-proven computer-based automatic check-out equipment provided by MSDS in Portsmouth. This system

verifies all the sub-system parameters through integration and test, including simulation of many aspects of spacecraft operation. All test cycles and results are stored for subsequent retrieval and analysis, and the data from the test under way were displayed in real time on a visual display unit for operator intervention if required.

MSDS also contributed to the satellite's communications system under sub-contract to Siemens, supplying the UHF receiver and amplifier and the S-band pre-amplifier.

The COSMOS Consortium

Others in the COSMOS Meteosat consortium were:

Aerospatiale (France) prime contractor, responsible for the assembly, integration and test of the spacecraft.

ECTA (Belgium) spacecraft power supplies and conditioning electronic controls.

Siemens (W. Germany) UHF and S-band radio equipment, including the MSDS sub-contract for radio equipment.

Selenia (Italy) design and construction of the synchronisation image channel, satellite housekeeping data collection and the S-band, UHF and VHF antennae.

MATRA (France) held the contract for the design and manufacture of the radiometer.

MBB (W. Germany) was responsible for the design and manufacture of the spacecraft structure, solar array, thermal control system, apogee boost motor and the mechanical ground support equipment.

These co-contractors employed the services of the following sub-contractors:

Aerojet (USA), Contraves (Switzerland), SAT (France), Terma (France), SRA (France), SAFT (France), SODERN (France), CIR (Italy) and Crouzet (France).

Acknowledgements
The editor wishes to thank the European Space Agency and Marconi Space and Defence Systems Limited for technical information used in this article.

SKYLAB SAFETY MISSION

America is planning to use a robot spacecraft with a television 'eye' to prevent the Skylab space station from falling on populated areas. The 75 ton station has been orbiting the Earth since May 1973 and was visited three times by astronauts during missions which lasted 28, 59 and 84 days.

If left alone, Skylab is expected to make its final plunge into the atmosphere in 1979-80. It could fall anywhere between 50° north and south of the equator although the chances are that it would descend over the sea. The ground track brushes the south coast of England.

Astronauts will launch the robot – called a Teleoperator Retrieval System – on an early flight of the NASA Space Shuttle. Released in orbit, it will manoeuvre up and attach itself to Skylab's axial docking port. Its low-thrust engines then can be used to nudge the station back into a higher orbit or by a braking impulse send it spinning harmlessly towards a prespecified area of the open sea. Russia's Salyut space stations have their own rocket motor to ensure re-entry over the Pacific Ocean at the end of a mission.

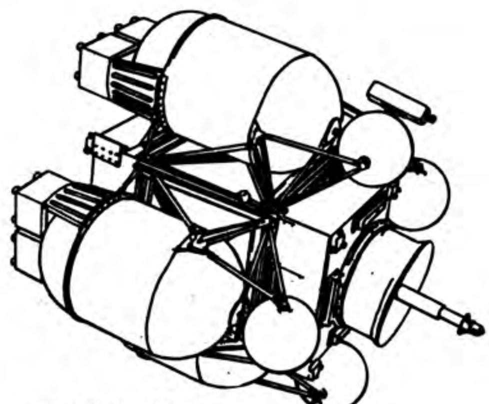
A whole range of spacecraft applications are envisaged including the ability to inspect, stabilise and manoeuvre payloads of many kinds in low-Earth orbit.

A NASA spokesman said the "free-flying low thrust craft will be carried to the vicinity of an orbiting spacecraft in the cargo bay of a Space Shuttle. An astronaut using television and a remote command and control system will guide the stage."

In the Skylab mission, it is planned to include the Teleoperator on the third Space Shuttle mission in 1979. "Through the television camera, mounted on the stage, the Shuttle crew will determine the condition of the satellite, then perhaps dock with it. Docking would be accomplished by using the cold gas thrusters."

NASA's Marshall Space Flight Center has been assigned management responsibility for development of the Teleoperator Retrieval System which will be built by Martin Marietta at an estimated cost of some $30 million.

The concept is an outgrowth of NASA in-house technology studies and Martin Marietta's work on earlier NASA projects such as the astronaut manoeuvring unit, free-flying teleoperator systems and work which the company has privately financed under their independent research and development programme.



Teleoperator Retrieval System.

The Teleoperator is expected to weigh about 8,000 lb. (3,630 kg) and have a maximum thrust of some 800 lb. (363 kg). Modular versions are envisaged, the largest having four propellant tanks for hydrazine propellants. Much of the vehicle will depend on off-the-shelf hardware. For example, the propellant tanks come from the Viking project and the thrusters are derived from the Transtage of the Titan programme. A probe/drogue docking unit has been specially designed for the Skylab mission by Martin Marietta.

Powered by the small hydrazine engines, the TRS can manoeuvre spacecraft into higher orbits. Once its mission is completed, it returns to the vicinity of the Shuttle *via* its own guidance and computer system. When in range, the Shuttle crew remotely guide it back into the Shuttle bay.

According to a company statement, a typical mission could lift a 10,000 lb. (4,536 kg) spacecraft into a 900 mile (1,448 km) orbit from the Shuttle low-altitude delivery orbit.

However, the ability to use the device to salvage Skylab will depend on the ability to meet a tight deadline. If sunspot activity is high during the late 1979 and early 1980 period, density changes in the upper atmosphere could cause the station to spiral in and burn up before the Shuttle mission can be flown.

ADVANCED LAUNCH VEHICLE SYSTEMS AND TECHNOLOGY

By M. W. Jack Bell*

NASA-sponsored studies of future commercial space applications, such as an advanced solar power system, have revealed the potential for enormous economic benefit if space cargo delivery costs can be reduced by an order of magnitude over those of the current Space Shuttle vehicle.

The Space Shuttle and its direct derivatives and improvements offer capabilities that can be used in support of initial orbital demonstrations of scaled versions of these future systems.

If operational models of Satellite Solar Power Stations are to be economically deployed, a second generation launch system will be required. In this paper the author reviews currently anticipated technical requirements for this class of orbital transportation system and presents conceptual configurations of two-stage low-altitude orbital delivery systems. He also identifies technology advances that would support the development of delivery systems and gives examples of possible single-stage-to-orbit configurations.

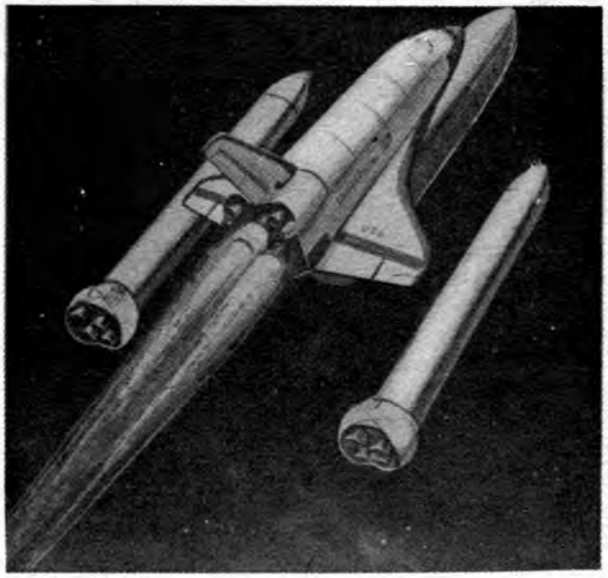


Fig. 1. Improved Space Shuttle with reusable liquid propellant rocket boosters.

Introduction

The Space Shuttle system being developed by the National Aeronautics and Space Administration (NASA) is expected to be the mainstay of the United States' space programme well into the 1990's. The utility and efficiency of the present design may be incrementally improved during that time, increasing payload delivery capabilities and extending mission durations.

In the meantime, it is probable that developments and prototype demonstration programmes will have proven the feasibility and economic desirability of various commercial operations in space, some of which are already under study by NASA. Among these concepts is the development of satellite solar power stations capable of supplying a significant portion of the Earth's needs with pollution-free energy [1]. Other concepts include the disposal or storage of nuclear wastes in space and the conduct of extensive manufacturing operations beyond the Earth's atmosphere [2]. With limited exceptions, the commercial feasibility of these concepts is dependent upon the development of advanced space transportation systems providing an order of magnitude reduction in payload delivery cost.

Interim Use of the Space Shuttle and its Derivatives

Much of the interim orbital development and scaled feasibility demonstration effort required as a prelude to full operation of these future commercial space applications can be accomplished with the Space Shuttle or derivatives of, or improvements to, this system.

Studies recently performed under the direction of the NASA Marshall Space Flight Center have defined configuration improvements to increase Shuttle payload delivery capability by fifty per cent or more while reducing cost per flight [3]. The approach having the lowest DDT&E cost is the replacement of the current solid rocket boosters with the fully reuseable ballistic liquid rocket boosters illustrated in Figs. 1 and 2. The boosters shown are sized to permit delivery of a 100,000 lb. payload to orbit on a due east launch. The engine compartments of these units would be sealed by clamshell doors after separation of the boosters from the Shuttle. These doors would serve as heat shields during entry. Parachutes and terminal retrorockets would be used for water landing.

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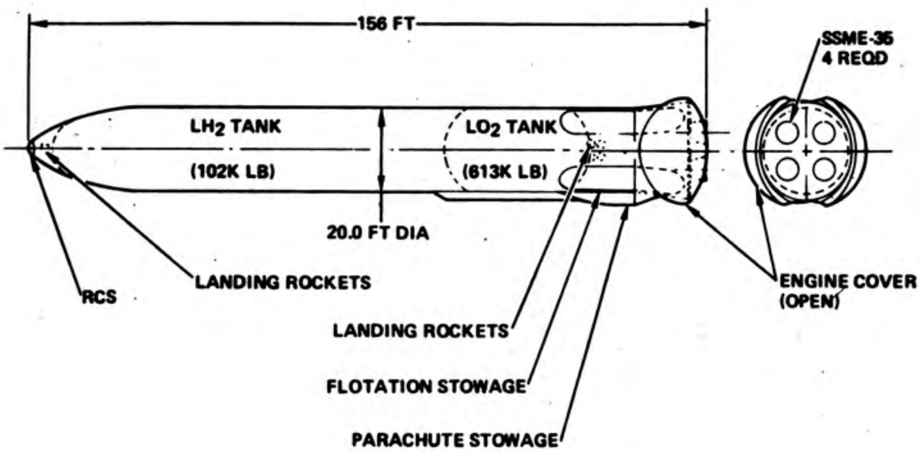


Fig. 2. Reusable liquid propellant rocket booster for Improved Space Shuttle Vehicle.

All illustrations Rockwell International

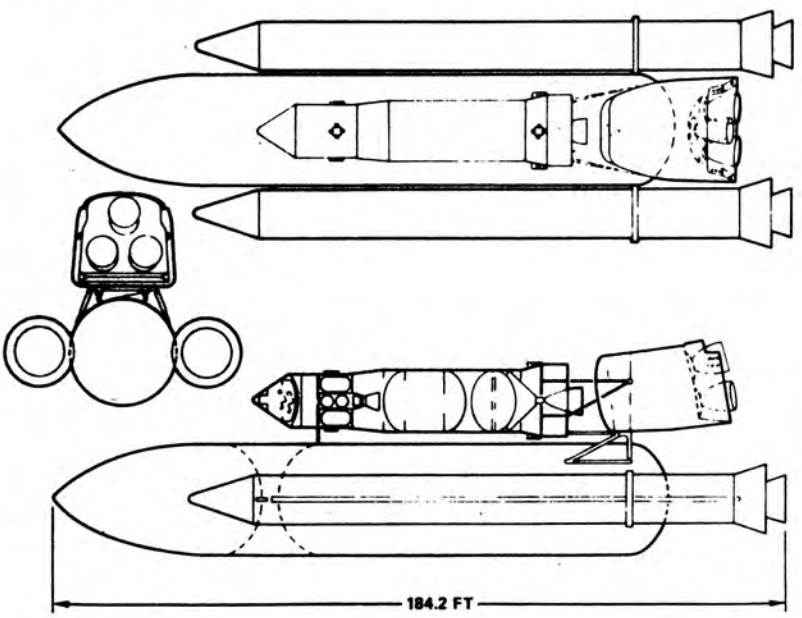


Fig. 3. Interim Heavy-Lift Launch Vehicle (IHLLV) Space Vehicle Derivitive.

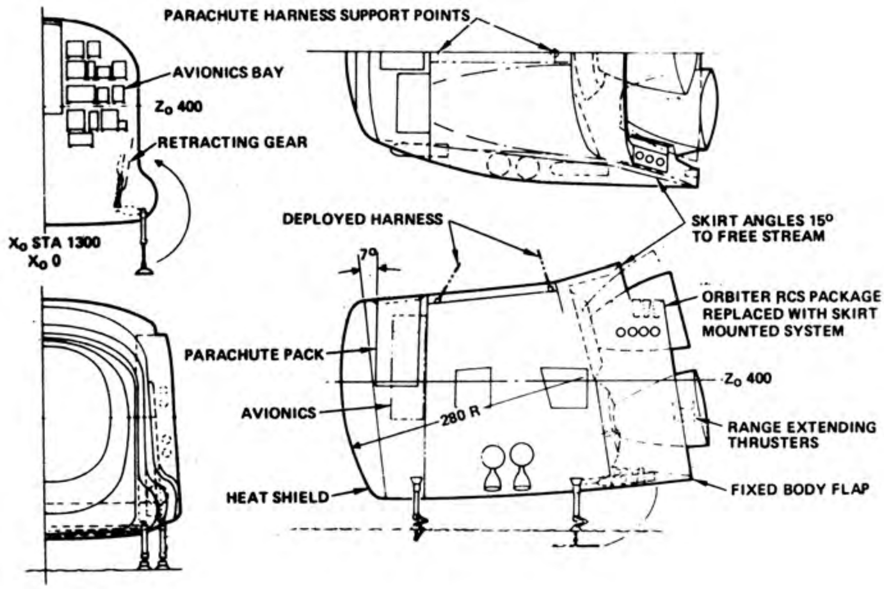


Fig. 4. IHLLV Ballistic Propulsion Module – Orbiter hardware application.

Other studies have shown the feasibility of utilizing Shuttle hardware to configure an interim heavy-lift launch vehicle (IHLLV) system (Fig. 3) capable of delivering 150,000 lb.† or more to orbit [4]. In this case, the Orbiter's aft fuselage compartment is converted into an entry vehicle, as shown in Fig. 4. On due east launches from Kennedy Space Center, this entry vehicle would be given 15 ft/sec. velocity increase following normal main engine cutoff. It would fly a nearly ballistic path into the Australian desert for landing, using a parachute-retrorocket Earth landing system. Estimated weights of the ballistic aft fuselage entry vehicle are summarised in Table 1.

If the reuseable liquid rocket booster were developed for Shuttle performance improvement and recurring cost reduction, it could be utilized to great advantage on the interim heavy-lift launch vehicle. The configuration portrayed in Fig. 5 could deliver payloads of 185,000 lb. to orbit; and if four of these units were used as shown in Fig. 6, the system could transport approximately 335,000 lb. into space. In the latter concept, propellant crossfeed is provided from one opposed pair of the boosters to the external tank. It is anticipated that the recurring cost per flight of these systems would be comparable to the cost per flight of the present Shuttle vehicle. The estimated weights of these systems are provided in Table 2.

Some of the preliminary studies of space industrialisation have indicated a potential requirement for a manned space transport vehicle to deliver pilot plant assembly personnel to low-altitude orbit [5]. If this requirement matures, it can be met economically by developing a transport kit for the present Space Shuttle Orbiter. Fig. 7 illustrates the installation of the Rockwell International kit concept, which would provide a space transport capable of delivering up to 74 passengers to low-altitude orbit.

† *Metric equivalents: Multiply feet by 0.3048 to obtain metres; statute miles by 1.609 to obtain kilometres and pounds by 0.4536 to obtain kilogrammes.*

All illustrations Rockwell International

Table 1. Ballistic Propulsion Module Weights

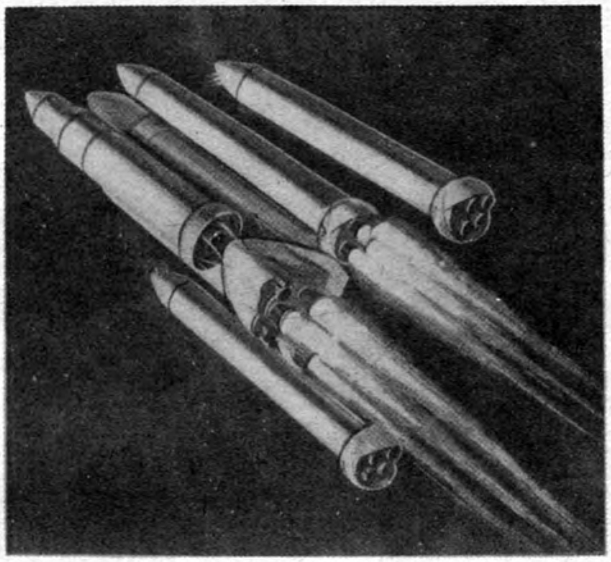
Item	Pounds	Item	Pounds
Structure	18,104	Dry weight	(73,085)
TPS/TCS/PVD	4,235	Residuals & reserves	(1,652)
Separation	1,272	Hydraulic water	145
Prime propulsion	28,248	Flash evap water	50
RCS	2,348	APU fuel	250
APU	2,403	OMS propellant	-
Electric power & distribution	1,393	RCS propellant	1,207
Surface controls	-	Useable	(5,433)
Avionics	6,324	Hydraulic water	300
Environmental control	538	Flash evap water	150
Parachute system	2,870	APU fuel	500
Retrorocket system	2,280	OMS propellant	-
Landing gear system	3,040	RCS propellant (max)	4,483
Miscellaneous	30		
Ballast	-		
Dry Weight	73,085	Gross weight	80,170

Advanced Launch Vehicle System Requirement

Engineering studies of several commercial space mission applications leave no doubt about their technical feasibility. The uncertainties are in the areas of total systems costs and return on investment. Technical and economic studies have established several clear requirements for a second generation space transportation system if delivery costs are to be substantially reduced over those of the Space Shuttle system:

1. All system hardware must be fully reusable.

2. All system hardware must be designed for fast operational turn-around (less than one week).



Right, Fig. 6. IHLLV with four reusable liquid propellant rocket boosters. *Below,* Fig. 5. IHLLV with two reusable liquid propellant rocket boosters.

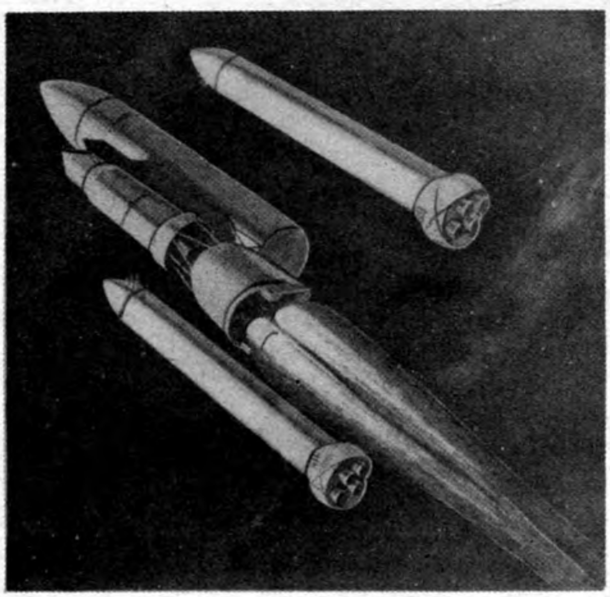


Table 2. Interim Shuttle Derivative HLLV.s

Item	Weights (thousands of pounds)		
	2 SRB's	2 LRB's	4 LRB's
Gross lift-off weight	4,457	3,658	5,579
Individual booster gross	1,286.5	871	873.5
Individual booster propellant	1,111	715	715
Individual booster at separation	175.5	156	158.5
Total all boosters gross	2,573	1,742	3,494
External tank gross	1,631	1,631	1,631
External tank propellant	1,553	1,553	1,553
External tank inert	78	78	78
Ballistic propulsion module	80	80	80
Payload adapter	3	3	3
Payload (50 x 100 n. mi. orbit)	170	202	359

3. Propellant costs must be constrained (tending to drive the design of the first stage to hydrocarbon or ammonia fuel).

4. Hardware must be developed for hundreds of flights, compared to the Space Shuttle Orbiter 100-flight requirement.

5. Hardware attrition rates must be low, comparable to manned aircraft.

6. Unfavourable impact of system operations on the environment must be judiciously constrained.

7. Although not definitively determined, the optimum payload delivery capability for supporting massive operations such as those associated with deployment of a number of large space solar power plants is on the order of 500,000 to 1,000,000 lb. per flight.

Advanced Staged Launch Vehicle Concepts

Preliminary studies conducted by NASA and various contractors have verified the feasibility of meeting space transportation system requirements with two-stage vehicles [1, 6]. Fig. 8 illustrates a Boeing two-stage, series burn, vertical take-off, horizontal landing (VTOHL) system configuration. This system, sized for delivery of an 840,000 lb. payload, has a gross lift-off weight of nearly 21 million pounds. It is necessary to reuse essentially all elements of this type of launch system, including the interstage structure, if recurring cost is to be minimised. For example, the replacement cost of an expended 20,000 lb. interstage structure might run as high as two million dollars. Hydrocarbon fuel used in the first stage would reduce the vehicle's size and avoid the relatively high cost of hydrogen fuel in the quantities required by a first stage for this class of launch system. Propellant costs are a significant percentage of the recurring cost per flight of an advanced space launch system that meets the requirements enumerated in the previous paragraph.

Figure 9 pictures a 1,000,000 lb. delivery capability, series burn, two-stage, low lift-to-drag, advanced launch vehicle configuration concept. In this approach, after separation the first stage coasts ballistically until reentry. At entry, the offset centre of gravity, resulting from locating the landing propellants in laterally offset tankage, facilitates trimming base forward to a low lift-to-drag attitude; roll modulation is applied to reach the designated landing site; and landing rockets are used for terminal touchdown. The second stage proceeds to orbit, delivering its payload. A retrograde impulse manoeuvre initiates second-stage descent along the desired Earth return path. Following entry, its trajectory is controlled in the same manner as for the first stage. Return of the first stage to the launch site presents a potential problem for this type of configuration. This issue might be resolved by the selection of a Pacific Ocean island launch site, which has another island located at the proper distance down range for landing, and by using an ocean surface return carrier. Estimated weights for this configuration are given in Table 3.

Both parallel burn and multiple staging provide potential advantages. In a parallel burn system, liquid propellant engines can be ignited and checked out prior to lift-off. In addition, parallel burn potentially permits a reduction in the number of engines required on the integrated vehicle. By using multiple staging, significant reductions in lift-off weight can be achieved for a given payload and impulsive velocity requirement. The Rockwell International heavy-lift launch vehicle (HLLV) concept illustrated in Fig. 10 capitalises on both these techniques. All engines are burning at lift-off. Propellants are crossfed sequentially from sets of pairs of opposed boosters into the final core stage. Booster pairs are separated at propellant depletion. The six-booster-plus-core configuration depicted thus is a four-stage vehicle. A low lift-off-to-payload weight ratio is obtained in this manner. Development costs are minimised as a result of the identical, relatively small, modular boosters; their size is expected to facilitate turnaround operations.

The six boosters are equally spaced around the core stage. Winged, air-breathing, cruise-back boosters are used in this configuration. The wings are retained in the folded position until after separation. Air-breathing engines supplement rocket thrust during lift-off and acceleration until they are shut down due to low atmospheric pressure. They are restarted after reentry and deceleration for sustained cruise flight return to the launch site.

The core stage is a medium lift-to-drag ratio configuration at hypersonic speeds. It reenters the atmosphere base first and uses landing rockets for terminal touchdown. Table 4 summarises the estimated weights for this configuration

Advanced Launch System Technology Requirements

Synthesis of a practical single-stage-to-orbit launch system

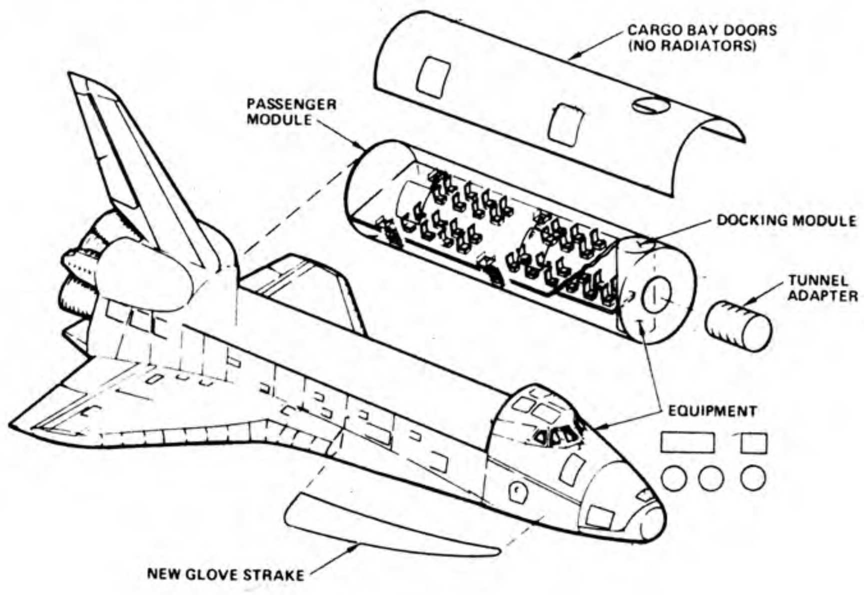
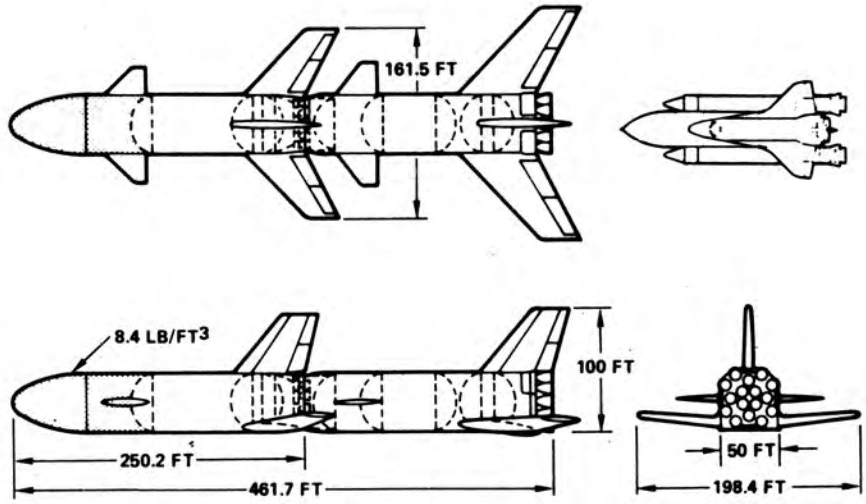
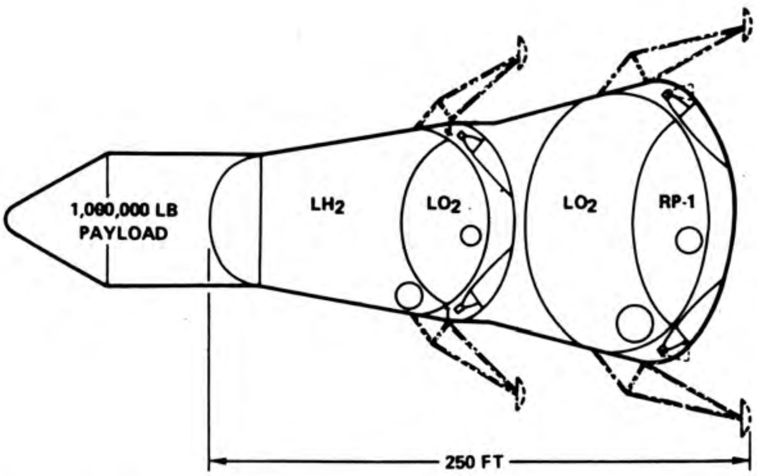


Fig. 7. 74-passenger Orbiter Transport.



Right, Fig. 8. Two-stage reusable VTOHL Launch Vehicle.



Left, Fig. 9. Two-stage Low Lift-to-Drag Launch Vehicle.

conceptual design has been a major goal of space flight enthusiasts for several decades. Preliminary studies have shown repeatedly that such systems are on the boderline of technical feasibility when reasonably optimistic assumptions are made about improvements in propulsion system performance and structural and equipment weights. Unfortunately, the propellant fraction required is so high that risk is great that inert weight growth or failure to accomplish predicted propulsion system performance would result in inability to achieve acceptable delivery capability. As a result, unless the required technology improvements are demonstrated, it is unlikely that a single-stage-to-orbit configuration would be selected for the second generation space transportation system.

Table 3. Two-Stage Low Lift-to-Drag Launch System

Item	Weight (pounds)
Gross lift-off weight	20,906,000
First-stage lift-off weight	14,992,000
First-stage propellant	13,277,000
First stage at separation	1,725,000
First-stage landing propellant	112,250
First stage at touchdown	1,612,750
Second-stage gross (including payload)	5,904,000
Second-stage ascent propellant	4,095,000
Payload delivered	1,000,000
Landing propellant	40,000
Second-stage at touchdown	769,000

Perhaps potentially the most profitable area for technological advancement is propulsion. Except for development of the high chamber pressure, staged combustion cycle, Space Shuttle main engine, activity in this area has been dormant for over a decade. Several specific developments deserve consideration:

1. An altitude-compensating nozzle capable of maintaining near-optimum expansion of propulsive gases from lift-off to near-vacuum ambient pressures.

2. Increased density propellants, including subcooling of cryogenic propellants and possible application of a dual fuel engine (using a high density, medium specific impulse propellant combination during lift-off and initial climb, followed by a high specific impulse propellant combination in near-vacuum, low climb angle flight at reduced thrust).

3. Air augmentation, which can provide, in theory, a

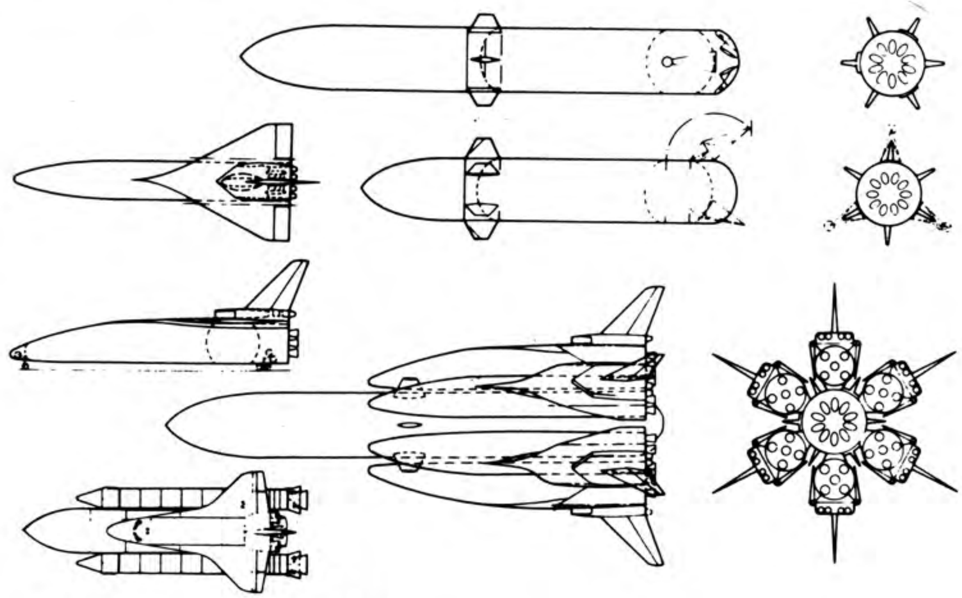


Fig. 10. Parallel Burn – Series Staged HLLV.

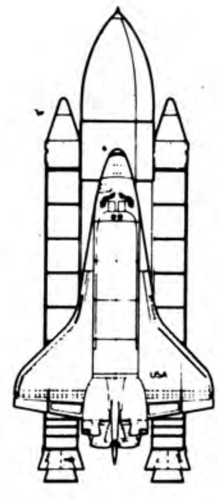


Fig. 11. ROMBUS 1-½ stage

Table 4. Parallel Burn, Crossfeed Launch System

Item	Weight (pounds)
Gross lift-off weight	13,230,000
Individual booster gross	1,466,333
Individual booster propellant	1,215,066
Individual booster at separation	251,267
Total 6 boosters gross	8,798,000
Core stage gross (including payload	4,432,000
Core stage ascent propellant	3,200,150
Payload delivered	600,000
Earth return propellants	75,700
Core stage at touchdown	556,150

substantial increase in average effective specific impulse. If air augmentation is to be effective, extra provisions to permit its application must be constrained to a small percentage of system inert weight. Options perhaps deserving evaluation include external burning of fuel and large cross-sectional area ducting of air for mixing with fuel-rich primary rocket propulsion system exhaust gases, where reheating would occur.

4. A lightweight, high energy density, high thrust-to-weight nuclear rocket capable of retaining all nuclear materials.

5. An integrated propulsion subsystem/airframe configuration, which is required to realise the full potential of these advancements. To date, space propulsion systems have been developed independently from the overall airframe, effectively prohibiting the efficient integration of propulsion and airframe functional requirements in the flight hardware. Integration may provide a large inert weight saving in ducting and nozzles for air-augmented systems and altitude-compensating nozzles for any system.

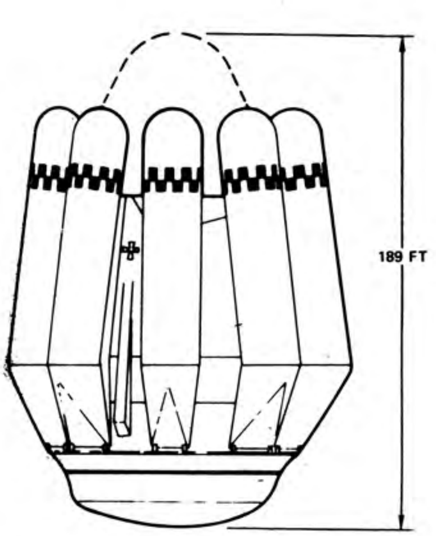
Structural design is a second discipline in which identified advancements can substantially improve launch systems effectiveness. The extensive use of composite materials in launch vehicle structures offers the potential of up to 25 per cent reduction in airframe inert weight. An improved, more rugged external insulation would contribute to reduced turnaround time and costs. Integral insulation/primary structure may be beneficial to improved propellant tankage design. "Hot" structures and actively cooled structures are other concepts worthy of further investigation and development.

Success in achieving these technological advancements would greatly enhance the prospects for a single-stage-to-orbit launch system and would also improve the efficiency of two-stage systems.

Single-Stage-to-Orbit Launch Systems

Studies performed during the 1960's [7, 8, 9] revealed the possibility of developing a low hypersonic lift-to-drag ratio configuration, similar to the stage in Fig. 9, as a single-stage-to-orbit delivery system. These studies indicated the necessity for an increased engine thrust-to-weight ratio over the present state-of-the-art and the use of an altitude-compensating nozzle along with substantial reductions in structural weight if such a system were to be feasible. At least two studies [7, 10] demonstrated the possibility of greatly reducing development risk and system weight through the use of expendable drop tanks. Another [8] showed the possibility of reducing lift-off weight through the use of air augmentation.

Illustrations of Philip Bono's ROMBUS [7] vehicle concept and the North American Aviation, Inc. (now Rockwell International), air-augmented single-stage-to-orbit (SSTO) concept [8] are provided in Figs. 11 and 12. The Bono ROMBUS (Fig. 13) using jettisonable hydrogen fuel tanks, was determined to have a lift-off weight of approximately 14 million pounds and to be capable of delivering up to one million pounds to orbit. The pure rocket-powered version of the North American Aviation, Inc., configuration was estimated to have a lift-off weight of 30 million pounds for delivery of a one-million-pound payload. The air-augmented versions of this configuration, illustrated in Fig. 14, were shown to be sensitive to augmentation system weight. The



Low Lift-to-Drag Launch Vehicle.

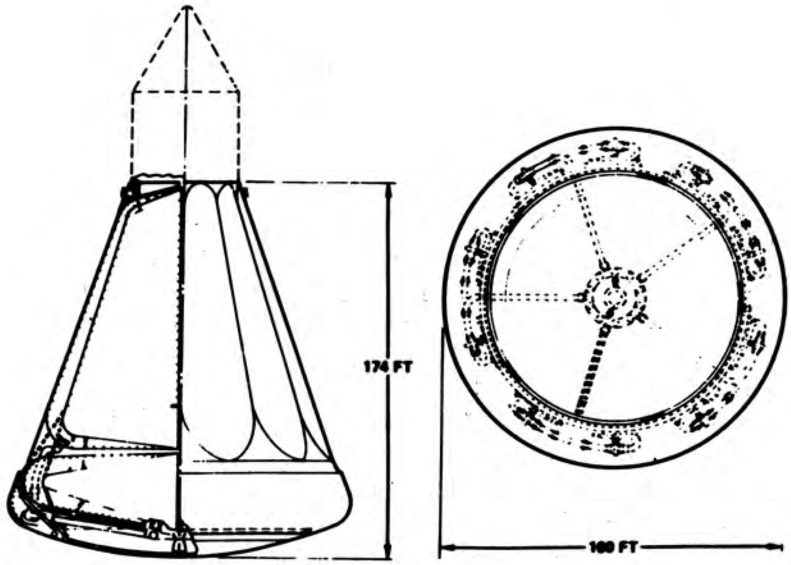


Fig. 12. SSTO Low Lift-to-Drag Launch Vehicle.

external burning ramjet-augmented configuration appeared to have merit primarily because of the relatively small weight increment required for ramjet installation, with preliminary studies indicating up to 30 per cent reduction in liftoff weight over the pure rocket system.

During the past few years, there have been several studies [11, 12] of winged, horizontal landing, single-stage-to-orbit launch systems. In these studies, benefits were derived by using a dual fuel rocket propulsion system in which a relatively high density hydrocarbon fuel was burned with oxygen from lift-off to some intermediate velocity followed by transition to hydrogen fuel. Although the hydrocarbon fuel/oxygen combination was substantially lower in specific impulse than the hydrogen/oxygen combination, the hydrocarbon fuel's higher density resulted in a major reduction in tankage volume and possibly in system inert weight over that required for a hydrogen only fuelled system. Fig. 15 illustrates the Boeing concept for a winged single-stage-to-orbit launch system. The lift-off weight of this configuration was stated to be 7,580,000 lb., with a propellant load of 6,500,000 lb. Its payload was given as 250,000 lb. This leaves approximately 830,000 lb. for the vehicle airframe, tankage, propulsion, crew, and expendables other than main propellants.

With suitable lightweight shielding, a high thrust-to-weight ratio nuclear rocket engine designed to prevent loss of nuclear material would provide an attractive advanced launch vehicle propulsion system. Studies and some preliminary hardware development work were performed on an engine of this type by the Los Alamos Scientific Laboratory for the Atomic Energy Commission under the Dumbo Rocket Reactor Project [13] during the late 1950's. The Dumbo reactor was designed with a high energy density, very high surface-to-volume ratio, laminar flow heat exchanger. The concept was advanced for its time and was competing for resources with the more conservative NERVA rocket reactor project. When

Below, Fig. 14. Air Augmentation Concepts for Low Lift-to-Drag Launch Vehicles.

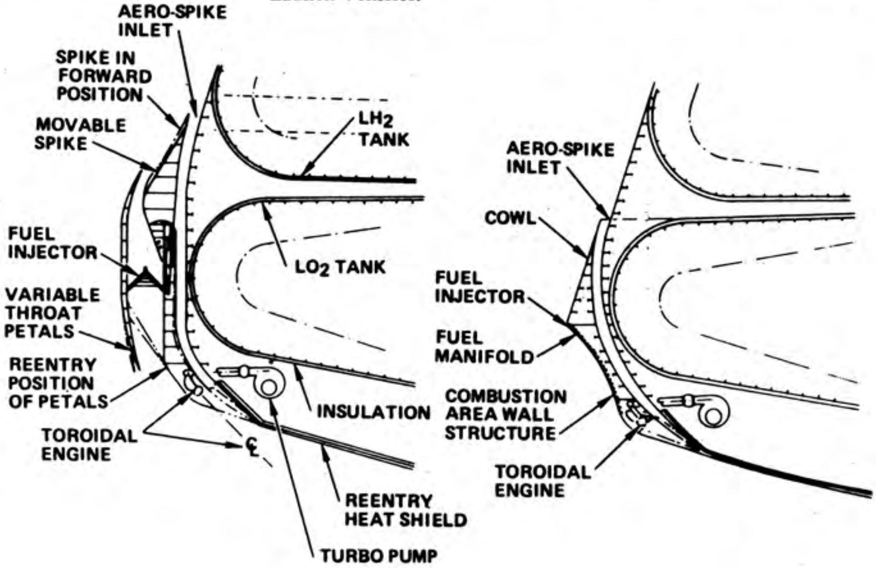


Fig. 13. Artist's impression of Rombus.

Phil Bono

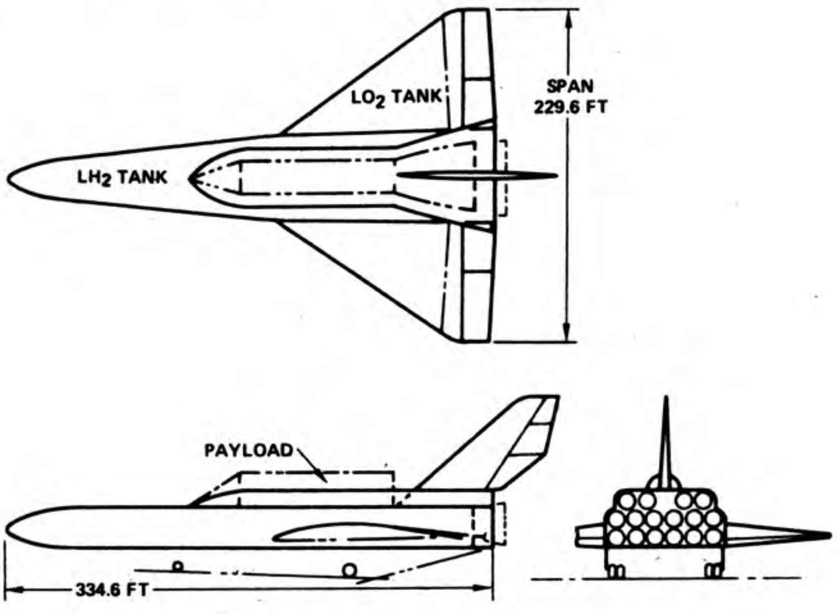


Fig. 15. Winged SSTO Launch Vehicle.

funding became too limited to support parallel developments, the Dumbo reactor project was terminated.

The Dumbo's developers were optimistic that complete engine systems with thrust-to-weight ratios of between 50 and 100 to 1 could be developed. Such an engine should permit ready attainment of the required propellant fractions on a fully reusable, winged, horizontal landing, single-stage-to-orbit launch system, particularly if attendant radiation problems could be solved. It is interesting to hypothesise the performance of an air-augmented version of such an engine with the enormous atmospheric heating capability of its hydrogen exhaust gas.

Conceptual studies are under way at Rockwell International, Space Division, to evaluate an air-augmented propulsion system potentially capable of substantially increasing thrust from static lift-off conditions up to Mach 4 or more. One of the principal concepts being evaluated is shown in Fig. 16. At lift-off, fuel-rich primary propulsion rocket engines are used as jet pumps to induce air flow around and past the rocket engines. Downstream of the rocket engine exhaust nozzle, the excess fuel is burned in the air. The heated gas expands against the plug nozzle boat-tail of the vehicle. As velocity builds up, a conventional ram rocket cycle is used. Excess fuel in the rocket is modulated to match the available air flow through the system. When air flow drops off as a result of reaching high altitude, the rocket engines are run at the optimum mixture ratio for vacuum operations. Preliminary results of these studies are encouraging.

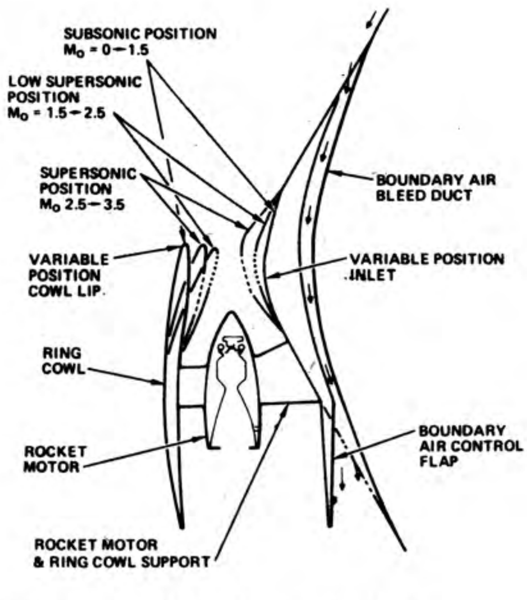


Fig. 16. Air-Augmented Rocket Propulsion Concept.

Summary

The basic capability exists today to initiate devlopment of an advanced launch system of greatly improved efficiency. Since it is probable that administrative go-ahead will not be forthcoming for a number of years and the Space Shuttle and its direct derivatives will fill the interim operational need, the available time should be used to extend technology in those areas where the economic benefits to advanced transportation systems are most promising: advanced propulsion, high-temperature lightweight structures, and integrated system configuration development. With these advancements incorporated in the next generation launch system, efforts to industrialise space must be successful.

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SPACE REPORT

A regular monthly review of Space Events and Technical Trends

PROBING SATURN'S RINGS

NASA officials have elected to fly Pioneer 11 just outside the rings of Saturn during the first encounter with the giant planet in September 1979. The craft is expected to pass some 30,000 km (18,000 miles) from the edge of the outer ring before swinging in, under the ring plane, to a distance of 25,000 km (15,000 miles) from the gas clouds of the planet itself.

The decision to fly outside the rings rather than pass inside them was taken jointly by Dr. Noel W. Hinners, NASA Associate Administrator for Space Science, and A. Thomas Young, Director of Planetary Programs. The main consideration was the space agency's desire to use Pioneer as a pathfinder for two Voyager spacecraft which are headed for Saturn encounters in 1980 and 1981. Voyager 1 is scheduled to encounter Saturn in November 1980 after flying past Jupiter, followed by Voyager 2 in August 1981. If all goes well at Saturn, the option is available for Voyager 2 to head for a Uranus encounter in 1986.

Pioneer's outside pass will cross the ring plane at about the same distance as the trajectory that would use Saturn's gravity to swing Voyager 2 towards Uranus.

Because of the uncertainties with the ring crossing even at 30,000 km from the outer edge of the rings, "it is essential for us to do everything we reasonably can to ensure Voyager's success," says Young. If Pioneer does not survive the rings at Saturn, NASA will almost certainly have to reassess its plan to continue to Uranus with Voyager 2.

"Alternatively, a successful Pioneer will greatly increase our willingness to comit Voyager 2 to the Uranus option, even if Voyager 1 has perhaps not achieved all of its objectives at Saturn," Young said. "Thus either survival or non-survival of Pioneer on the outside trajectory can have an important influence on Voyager plans, and therefore on achieving the maximum science return from all three spacecraft."

Chances of surviving the outside pass are estimated to be much greater than those of surviving an inside pass, which would have brought Pioneer as close as 6,000 km (3,700 miles) to the planet. However, the Pioneer project office at Ames Research Center, Mountain View, California, and most of the Pioneer scientific investigators, have favoured a trajectory which would have taken Pioneer *inside* the rings.

Pioneer was targeted for Saturn after returning pictures and data of Jupiter in December 1974. A sister spacecraft, Pioneer 10, was the first to encounter Jupiter in December 1973. The 1979 Pioneer flyby will mark the first encounter with Saturn and its rings.

The rings lie in Saturn's equatorial plane, which is tipped 27 degrees to the orbital plane of Saturn. Spectroscopy shows that they are made primarily of water ice or ice-covered silicates.

The individual particles probably vary from less than a millimeter to more than 10 metres, but most are a few centimetres in size – about as big as a snowball.

Three distinct rings can be seen. The inner or "crepe" ring begins about 17,000 km (10,000 miles) from the

SATELLITE DIGEST - 114

A listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information sources include the Space Department of the Royal Aircraft Establishment at Farnborough, NASA, Novosti and both the popular and specialist press. For a more detailed summary, see Satellite Digest – 111, January, 1978.

Continued from March issue, p. 117]

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Soyuz 25	1977 Oct 9.11	Sphere + cone-cylinder	7.5 long	194	240	51.64	88.78	Tyuratam-Baikonur
1977-99A	2.03 days (R)	+ antennae	2.3 dia	265	309	51.60	90.22	A-2
	1977 Oct 11.14	6570?		329	353	51.62	91.29	USSR/USSR (1)
Cosmos 958	1977 Oct 11.64	Cylinder + sphere +	6 long?	257	351	62.81	90.59	Plesetsk
1977-100A	12.6 days (R)	cylinder-cone?	2.2 dia?	323	420	62.81	91.96	A-2
	1977 Oct 24.2	5500?						USSR/USSR(2)
Cosmos 959	1977 Oct 21.42	Cylinder?	4 long?					Plesetsk
1977-101A	40 days		2 dia?	146	850	65.84	94.57	C-1
								USSR/USSR(3)
ISEE 1	1977 Oct 22.58	16 sided cylinder	1.61 long					ETR
1977-102A	6 years?	340	1.73 dia	337	137904	28.95	3440.9	Delta
								NASA/NASA(4)
ISEE 2	1977 Oct 22.58	Cylinder	1.14 long					ETR
1977-102B	6 years?	158	1.27 dia	341	137847	28.96	3439.1	Delta
								ESA/NASA(4)
Cosmos 960	1977 Oct 25.23	Cylinder + paddles	2 long?					Plesetsk
1977-103A	10 years	900?	1 dia?	502	546	74.04	95.13	C-1
								USSR/USSR
Cosmos 961	1977 Oct 26.22	Cylinder?	4 long?	125	302	66	88.76	Tyuratam-Baikonur
1977-104A	0.78 day		2 dia?	269	1421	66.4	101.8	F-1-m
	1977 Oct 26							USSR/USSR (5)
Molniya-3H	1977 Oct 28.07	Cylinder-cone + 6	4.2 long?					Plesetsk
1977-105A	12 years?	panels + 2 antennae	1.6 dia	428	40769	62.80	734.89	A-2-e
		1500?						USSR/USSR
Transat	1977 Oct 28.20							WTR
1977-106A	2000 years			1069	1107	89.92	107.03	Scout
								DoD/NASA
Cosmos 962	1977 Oct 28.66	Cylinder	1.3 long?					Plesetsk
1977-107A	1200 years	700?	1.9 dia	968	1012	82.96	104.93	C-1
								USSR/USSR(6)
Meteosat 1	1977 Nov 23.07	Cylinder	3.20 long	198	37002	27.48	654.78	ETR
1977-108A	indefinite	697	2.10 dia	34913	35692	0.73	1411.5	Delta
								ESA/NASA(7)
Cosmos 963	1977 Nov 23.07	Spheroid + 2 paddles?	1.6 dia?					Plesetsk
1977-109A	3000 years	650?		1182	1210	82.93	109.35	C-1
								USSR/USSR

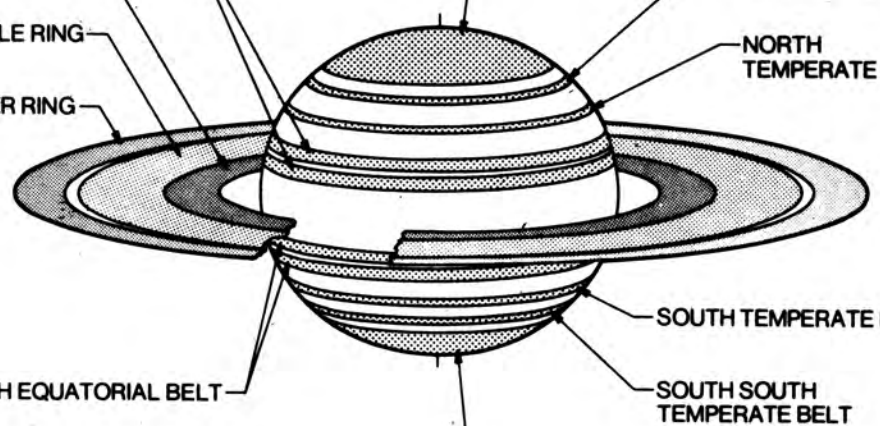
Amendments and decays:

1967-46A, Cosmos 159 may have decayed around 1977 Nov 11.
1972-81A, Molniya-1W decayed 1977 Nov 1, lifetime 1844 days.
1973-07A, Molniya-1Y decayed 1977 Oct 23, lifetime 1723 days.
1977-97A, Salyut 6 was manoeuvred upward into a 91.25 minute orbit on 1977 Oct 3. A further manoeuvre on 1977 Nov 28 resulted in perigee 345 km, apogee 360 km, inclination 51.6 degrees and period 91.38 minutes. Salyut 6 is a modified design with a second docking port on the instrument unit; this was achieved by re-arranging the layour of the manoeuvring engine.

Supplementary notes

(1) First attempt to place a crew aboard Salyut 6 which failed ".. when deviations in the planned docking routine occurred.." No attempt was made to use the second docking unit so there is a possibility of damage to the docking apparatus of Soyuz. The crew consisted of Lt. Col. Vladimir Kovalenok, the flight commander and civilian flight engineer Valery Ryumin.
(2) Orbital data are at 1977 Oct 11.7 and 1977 Oct 15.5.
(3) Target for satellite interception tests (see note 5).
(4) Pair of satellites designed to make joint measurements of the effect of the Sun on near-Earth space. A third satellite is due for launch during 1978 summer; this will carry out simultaneous measurements from the Earth-Sun libration point. The use of a pair of craft separated by some distance will allow more precise determination of the origins of disturbances in the plasmapause and magnetopause. ISEE 1 was built at NASA's Goddard Space Flight Center. ISEE 2, which carries an orbital adjustment engine, was built for the European Space Agency.
(5) Satellite interceptor using Cosmos 959 as its target. Orbits shown are approximate and are at 1977 Oct 26.2 and 1977 Oct. 26.3, Cosmos 961 re-entered soon afterwards.
(6) Cosmos 962 may be a navigation satellite.
(7) European-built meteorological satellite in geostationary orbit as part of a worldwide programme of weather observation. Meteosat collects data by direct measurement, photography and interrogating weather balloons and buoys. Orbital data shown are at 1977 Nov 23.1 and 1977 Nov 25.4. The second orbit shown allowed the satellite to drift from its injection point at 91°E to its operating position on the Greenwich meridian which it reached about 1977 Dec 8.

SATURN has an equatorial radius of some 60,000 km (37,300 miles); the polar radius is considerably smaller, about 53,500 km (33,340 miles). The dynamic flattening is caused by Saturn's rapid axial rotation and increased by its low density. The planet has a volume 815 times greater than Earth's but a mass only 95.2 times greater. A day on Saturn is only 10 hr. 14 min. – 18.5 minutes longer than a day on Jupiter. The planet completes one orbit of the Sun in 29.46 Earth years. Its average distance from the Sun is 9.5 A.U.'s. Major atmospheric constituents are hydrogen and perhaps helium; minor constituents include methane and ammonia. Temperature at tropopause is about 77 deg K (-321 deg F); pressure at tropopause about 0.17 atmospheres. Beneath the clouds, temperatures and pressures increase rapidly. It is not known if Saturn has a solid surface.



planet's visible cloud surface and extends for 15,000 km (10,000 miles) to 32,000 km (20,000 miles). The second ring begins at that point and extends for 26,000 km (16,000 miles) to a distance of 58,000 km (36,000 miles) from the planet. There, a phenomenon known as Cassini's Division breaks the rings' continuity. Cassini's Division has a width of some 2,600 km (1,600 miles).

The outer ring begins 60,000 km (38,000 miles) from the equator of Saturn and appears to end 16,000 km (10,000 miles) farther away at a distance of 76,000 km (48,000 miles).

Cassini's Division is real. It is explained by a phenomenon in celestial mechanics. Any particle at that distance would have an orbital period of 11 hours 17½ minutes, just half the period of the satellite Mimas. The particle would be nearest Mimas at the same place in its orbit every second time around. This repeated gravitational perturbation would eventually move the particle to a different distance.

Accurate measurements of the ring thickness are not possible but limits have been placed. They appear to be somewhere between 1 and 4 km (0.6 to 2.5 miles).

Until recently there was no evidence that Saturn has a magnetic field. Neither decimetric nor decametric radio emissions had been observed – the kind of "radio noise" from Jupiter that was evidence for its magnetic field. But radiometric observations from the Earth-orbiting satellite IMP-6 have provided indirect evidence for a magnetic field. If a magnetic field is present, it is probably distorted by the rings. Direct measurement of any magnetic field and associated trapped radiation is one of the primary goals of the subsequent Voyager mission.

Like Jupiter, the principal constituents of the Saturnian atmosphere are thought to be hydrogen and helium. Three molecules have definitely been detected in Saturn's atmosphere: hydrogen (H_2), methane (CH_4) and ethane (C_2H_6). Radio observations provide indirect evidence for ammonia (NH_3) at atmospheric levels inaccessible to optical measurements. No other molecular or atomic species has been detected.

Also, like Jupiter, Saturn is believed to be composed of materials in about the same ratio as the Sun, formed into the simplest molecules expected in a hydrogen rich atmosphere.

Saturn appears to radiate nearly twice as much energy as it receives from the Sun. In the case of Jupiter, that radiation has been explained as primordial heat left over from the time, about 4,600 million years ago, when the planet coalesced out of the solar nebula. The same may be true for Saturn. Convection is the most likely transport mechanism to carry heat from the interior of the planet to the surface.

Saturn has cloud bands similar to Jupiter's, although they are harder to see and contrast less with the planetary disc. Photographs confirm that Saturn's bland appearance is real. The blandness may be a result of lower temperatures and reduced chemical and meteorological activity compared with Jupiter or a relatively permanent and uniform high altitude haze.

The principal features of Saturn's visible surface are stripes that parallel the equator. Six dark belts and three light zones have been seen continuously over 200 years of observations.

Spots have been observed in the upper atmosphere of Saturn. Unlike the Great Red Spot of Jupiter they are not permanent nor are they easily identifiable. The spots that have been observed have lifetimes up to a few months. Sometimes they are light, sometimes dark. They are confined to a region within 60 degrees of the equator and typically are a few thousand kilometres across. They may be comparable to hurricanes on Earth.

Saturn has 10 known satellites. The most recent discovery was Janus, found in 1966 by Audouin Dollfus. Janus has been seen in only a few photographs. It appears to travel in the plane of Saturn's rings and near them. Its low albedo and proximity to the rings make Janus difficult to observe except when the rings are edge-on to Earth and recent studies indicate that at least two separate satellites are masquerading under the name of Janus.

The largest known satellite in the Solar System is Saturn's satellite Titan. Titan has a diameter of 5,800 km (3,600 miles) and is known to have an atmosphere. In 1944, the late Dr. Gerard Kuiper detected a methane atmosphere on Titan. Titan's atmospheric pressure may be comparable to Earth's. Other molecules identified include ethane and probably acetylene and many scientists believe there is also a major undetected gas present. The most likely candidate is nitrogen. Some scientists believe organic compounds may be present on the surface of Titan, leading some to suggest it as a possible abode of some primitive life forms.

Iapetus is another Saturnian satellite that draws scientific interest. Its brightness varies by a factor of about five as it rotates on its axes, indicating that one face is bright and the other dark. The light face appears to be covered with ice but the composition of the dark face is unknown.

Saturn's rings have been a curiosity to astronomers since their discovery. Their origin is unknown but a number of hypotheses have been put forward. They might be the remains of some early satellite broken up by gravitation or remnants of the primordial material that somehow became trapped in orbit. Their age is unknown.

IUS ENGINE TEST

The first flight of the Interim Upper Stage (IUS), being developed for the United States Air Force by the Boeing Aerospace Company, moved a step nearer on 19 December with the successful test firing of its large solid propellant rocket motor at the Arnold Engineering Development Center at Tullahoma, Tennessee.

The 91 in. (231 cm) diameter motor, produced by the Chemical Systems Division of United Technologies fired for 157 seconds in a horizontal position at a simulated altitude of 100,000 ft. (30,480 m). No difficulties were encountered during the unusually long burn.

Made of Kevlar 49 fibres and epoxy resin, the flight configuration motor case contained some 20,000 lb. (9,072 kg) of HTPB propellant and was fitted with a light-weight nozzle throat of three-dimensional carbon/carbon – an advanced composite material. Also tested for structural and thermal integrity was the Chemical Systems Division's 'Techroll' joint. The motor was fired with the nozzle in the null or zero deflection attitude. The 'Techroll' joint is a fluid-filled, constant volume bearing which, used to connect a nozzle to a rocket motor case, allows easy pivoting of the nozzle by the steering system.

Owing to the long burning time requirements, nozzle survivability has been considered a key challenge in developing the large IUS motor. Three earlier tests made to evaluate nozzle materials and the latest test of an operational-type motor have shown the advanced light-weight nozzle to be reliable.

The propellant used in all four test firings, and the one which will power the operational IUS motors, is composed of 86 per cent solids with 18 per cent aluminium.

The fifth and final test of the IUS Validation Phase was being prepared at the Air Force Rocket Propulsion Laboratory, Edwards AFB, as we closed for press. That test was designed to evaluate another type of advanced nozzle integral throat and nozzle (ITE).

Full-scale development of the Interim Upper Stage propulsion system was due to begin on 1 March.

The Chemical Systems Division of United Technologies will develop and produce the full propulsion system of both the IUS rocket motors, the one discussed above which provides an average thrust of 47,000 lb. (21,319 kg), and a smaller one with 27,000 lb. (12, 247 kg) of thrust.

The IUS will be used to extend the capability of the NASA Space Shuttle in various directions. Carried into orbit within the cargo bay, it will send payloads into higher orbits or on escape missions to the planets. It will also fly as an upper stage on an advanced version of the USAF's Titan III Standard Launch Vehicle, designated the T34-D which is expected to replace present Titan III models in the 1980's. The first launch is expected to be made in early 1980 from Cape Canaveral.

FAR SIDE MOON PROBE?

The Soviet Union may attempt to soft-land an automatic station on the far side of the Moon before 1980, according to information reaching the West. Russian geologists are said to be particularly interested in the Van de Graaf region at about 27 south latitude, 172 east longitude.

A mission of this kind – either a Lunokhod rover or a soil sampler – requires a communications satellite in lunar orbit to complete the command link with Earth. In the case of a sample-return vehicle, a more complex engineering solution would be needed to eject the craft into the prescribed Earth transfer trajectory.

The last successful Soviet soil sampling mission was carried out in the Sea of Crises by Luna 24 in August 1976.

A lunar far-side sampling mission would have the advantage of testing techniques for returning a soil sample from Mars in the 1980's, in which Soviet space officials have also expressed interest.

MOST EFFICIENT CHEMICAL ROCKET'

The Rocketdyne Division of Rockwell International has completed a series of tests on an advanced space engine that might power a Space Tug in the late 1980's. Major components of the engine were developed under several contracts with NASA's Lewis Research Center in Cleveland, Ohio, writes Dave Dooling. They were tested at Canoga Park, California.

A Rocketdyne spokesman said the engine is the most efficient chemical rocket ever designed. Burning hydrogen and oxygen, it has a specific impulse of 478 seconds, five higher than planned and 23 higher than the Shuttle main engine. Such high efficiency was achieved by using a preburner, like the main engine, to power turbines and recover

energy, and an extra wide expansion bell that covers 400 times the area of the engine nozzle.

An operational engine would have an operational lifetime of 10 hours and 300 ignitions, and could be used on manned vehicles.

Longest test run on the engine was only four seconds, but the spokesman said that was long enough to demonstrate engine stability. He said that after two seconds temperatures and pressures level out and the engine can run for hours.

Thrust was only 21,500 lb. (9,752 kg), sufficient for moving payloads to different Earth orbits or sending them to other planets. The advanced space engine is a part of Lewis' propulsion technology programme. The powerhead assembly, heart of the ASE, integrates all the key functional engine components into a closely coupled welded assembly that results in a compact package of minimum weight and volume. Conversion of potential propellant energy to vehicle kinetic energy is maximized by use of a staged-combustion cycle and a 400:1 expansion area ratio nozzle. This nozzle, when combined with the highly efficient combustor, will produce the highest performance O_2/H_2 rocket thrust chamber ever designed and fabricated. This high efficiency will permit the ASE to perform its mission with less propellant bulk, which releases premium space and weight to high-value payload use. Operation of the ASE will be economical because of its long life, resusability, and minimum-maintenance design. These characteristics will reduce recurring costs and ground turnaround time. The retractable two-position nozzle and high operating pressure of the ASE result in a very compact engine design. With its nozzle retracted, the engine occupies a volume approximately 4 ft. (1.2 m) long by 4 ft. (1.2 m) diameter, thus employing available space efficiently and/or reducing required interstage structure.

Applications for the ASE include the all-up Space Tug, high-energy upper stages, and future space transportation systems. Potential missions for these vehicles cover deployment, maintenance, and retrieval of payloads in Earth orbit including synchronous orbits, space station operations, lunar and planetary exploration, and deep space research.

Advanced Space Engine (ASE) Description

Nominal Characteristics	
Thrust, pounds	2 20,000
Chamber Pressure, psia	2,000
Nozzle Expansion Area Ratio	400:1
Propellants	Liquid oxygen and liquid hydrogen
Mixture Ratio (o/f)	6.0
Propellant Flow, lb/sec	42.25
Specific Impulse, seconds	473.4
Gimbal Angle degrees	±7
Service Life, hours	10
Thermal Cycles	300
Weight, pounds	384
Diameter, inches	48.5
Engine Length, inches	
Nozzle Retracted	50.5
Nozzle Extended	94.0

SKYLARK'S 'MINI-FACTORY'

In the frozen north of Sweden, inside the Arctic Circle, the first BAe Skylark sounding rocket in the West German Texus programme was successfully launched from Esrange near Kiruna on 13 December 1977. Two helicopters were standing by in the recovery area as the rocket floated down to Earth on its parachute 16 minutes after launch. With the lakes frozen over, there was no danger of the payload getting wet. It was recovered in pristine condition 45 miles (72 km) north of Esrange and flown back to the range, writes Dagmar Heller.

The rocket had reached a height of 163 miles. During the 6½ minutes it was almost weightless, the experiments it carried were a hive of activity, a miniature factory in space.

In five modules, each containing one or more experiments, metals and alloys were melted and solidified, electrolysis experiments were carried out, and the interaction of different liquids was studied. All this activity was with one aim in mind – to provide data so that space-proven equipment and useful experiments can be flown in Spacelab from 1980 onwards.

While this launch makes Skylark the first European rocket to fly experiments under zero-g conditions, it is the foresight of the West German Ministry of Technology, with the co-operation of the Swedish Space Corporation, that has made it possible.

The Germans have embarked on a programme to encourage their scientists and industrialists to think in terms of what can be gained by using the space environment (see 'Getting Aboard Spacelab,' *Spaceflight*, September 1976, pp. 302-303).

To bridge the three-year gap before the first flight of Spacelab, and to maintain the interest of would-be experimenters, West Germany planned to launch five Texus rockets in a programme managed on behalf of the German Ministry by the German research institute DFVLR, with VFW Fokker/ERNO as the main contractor; ERNO was responsible for the manufacture of the equipment for all the German experiments.

The Swedish Space Corporation designed its own. Like the West Germans, the Swedes are thinking ahead to Spacelab, and their part of the payload consisted of ten mirror furnaces plus two gradient furnaces, all in a Skylark module 1½ in. in length. It was designed by the Swedish Space Corporation, and the samples of metals and alloys were supplied by the Royal Institute of Technology.

It was an extremely ambitious project which involved many long hours of work, but according to Professor Hans Fredriksson, of the Institute, the Swedish Space Corporation had "done it just as we wanted, and they are marvellous."

The eight German experiments flown in Texus I included an acoustic levitation chamber in which an 8 mm diameter (just under 0.5 in) sample of antimony-copper was levitated melted and solidified during zero-g. The chamber was developed by the Battelle Institute of Frankfurt and the sample supplied by Prof. Dr. Ahlborn of Hamburg University.

Dr. Ahlborn is investigating the crystallisation and segregation of various metals in the absence of convection and density and in the decontamination of crucibles in which the metals have to be melted on Earth.

Other interesting experiments from industry flown in a multi-purpose furnace included one looking at methods of improving the heat-resistance of gas-turbine blades, and the possibilities of melting lead and aluminium together instead of tin and aluminium to manufacture plain bearings.

Tin is now 15 times more expensive than lead, and while four or five per cent of lead is known to have good properties for this type of bearing, the production of a homogenous mixture is difficult to obtain on Earth because the lead sinks to the bottom during the solidification process. By cooling the molten mixture during zero-g a more uniform distribution should be obtained.

According to Arne Helger, head of Esrange, preliminary evaluation of the experiments shows 99 per cent technical and scientific success.

SPACEFLIGHT

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Correspondence and manuscripts intended for publication should be addressed to the Editor 12, Bessborough Gardens, London, SW1V 2JJ.

Opinions in signed articles are those of contributors, and do not necessarily reflect the view of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

15th European Space Symposium
Theme **APPLICATIONS SATELLITES**
To be held in Breman, Germany, on **8-9 June 1978.** Co-sponsored jointly by the DGLR, AAAS, AIDAA and BIS.

Subject areas will emphasise the following aspects:

(1) Telecommunications Satellites.

(2) Meteorological/Remote Sensing Satellites, User and Ground Facilities.

Offers of papers are invited. Further information is available from the Executive Secretary.

33rd Annual General Meeting
The 33rd Annual General Meeting of the Society will be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **22 June 1978** at 6.30 p.m. A detailed Agenda appears in this issue of *Spaceflight.*

Nominations are invited for election to the Council. Forms can be obtained from the Executive Secretary. These should be completed and returned not later than **11 May 1978.**

Should the number of nominators exceed the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all members.

Southern California Meeting
Theme **SPACE: TODAY'S HOPE, TOMORROW'S REALITY**
To be held in Los Angeles, California, USA late **SEPTEMBER** – early **OCTOBER 1978.** A Symposium in three parts:

Part 1 – Survival: Holding the Fort
Part 2 – Reconstruction: Spring Cleaning
Part 3 – Expansion: New Horizons

Offers of paper are invited. Further information is available from Mr. A. A. J. Hooke, M/S 114-122, Jet Propulsion Laboratory, 4800, Oak Grove Drive, Pasadena, Calif. 91103, USA.

Film Show
To be held in the Botany Lecture Theatre, University College London, Gower Street, London, WC1 on **11 October 1978,** 6.30-8.30 p.m.

The programme will be as follows:

(a) Reading the Moon's Secrets
(b) Mercury, Exploration of a Planet
(c) HEOA, the New Universe
(d) Images of Life

Admission tickets are not required. Members may introduce guests.

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COVER

INTERNATIONAL COSMONAUTS. Docking of the first international space crew with the Salyut 6 space station was achieved just as the resident crew were about to break America's 84-day record for the longest stay in space. When Soyuz 28 cosmonauts Alexei Gubarev and his Czech companion Capt. Vladimir Remek climbed aboard the station, it was 3 March and everything was going smoothly. Georgi Grechko and Yuri Romanenko had completed the bulk of their extensive programme. EVA had been accomplished, there had been two dockings and separations of supply craft, joint activities by four men had been carried out without difficulty and Salyut 6 had been successfully re-fuelled. Now the first step had been taken under the new Intercosmos programme in which cosmonauts from other socialist countries would "conduct research of increasing volume and complexity aboard Salyut space stations." Between now and 1983 will come cosmonauts from Poland, East Germany, Bulgaria, Hungary, Cuba, Mongolia and Romania. Captain Vladimir Remek, 29 (top), was selected as a candidate for the first mission in 1976. He is a military pilot in the Czechoslovak People's Army. His Flight Commander, Alexei Gubarev, 49, made his first flight as commander of Soyuz 17 with Georgi Grechko; they docked with Salyut 4.

Novosti Press Agency

MILESTONES

February

7 International Ultra-violet Explorer (IUE), launched from Cape Canaveral on 26 January, obtains stellar spectrum of B3V 'calibration star' *Eta Ursa Majoris* (visual magnitude 1.8) located in the handle of the Plough.

15 Salyut 6 cosmonauts Yuri Romanenko and Georgi Grechko begin technological experiments using the 'Splav 01' (Alloy) electric furnace. The furnace, a control panel and other equipment, were ferried to the station in the unmanned cargo ship Progress 1 on 22 January. The furnace, installed in a special airlock, produces a temperature of more than 1,000°C and is computer-controlled to give an accuracy within five degrees. Experiments are related to welding and soldering in space and the creation of new composite materials (see page 186). Cosmonauts observe Northern Lights over North America and estimate they reached 500 km altitude.

16 Japan launches ionospheric survey satellite ISS-B from Tanegashima Space Center by Japanese 'N' rocket based on licence-built Thor. Orbit ranges between 978 and 1,222 km inclined at 69.3 deg to equator. *[Exos-A, which employs an ultraviolet TV camera to study the aurora, was launched on 4 February by a Japanese-built Mu-3H rocket from the Kagoshima Space Center. The orbit ranges between 347 and 2,460 miles (558 and 3,958 km). The 227 lb. (103 kg) satellite is named Kykkoh. Ed.].*

17 Salyut 6 cosmonauts continue experiments with the 'Splav' electric furnace. They also report on silver clouds in the Earth's atmosphere. Such clouds are usually in the polar regions at an altitude of some 80 km. The cosmonauts have made drawings and taken dozens of photos which show that the silver clouds divide clearly into three layers differing in temperature from -130 deg to -150 deg.

20 Orbital parameters of Salyut 6/Soyuz 27 are 332 x 347 km x 51.6 deg; period 91.1 min.

23 Orbit of Salyut 6/Soyuz 27 is changed to 335 x 364 km x 51.6 deg; period 91.4 min, using the station's manoeuvre engine.

24 Salyut 6 cosmonauts use closed-cycle liquid helium system to cool the crystal receivers of a BST IM sub-millimetre infra-red telescope to -269 deg. Cosmonauts aligned the telescope's control system in conjunction with a small optical telescope by setting it to follow the movements of Jupiter and Sirius. Programme included observation of the centre of the Galaxy, Orion nebula and interstellar hydrogen clouds. Instrument was also focussed on the Earth "to measure regions of the upper atmosphere significant in weather forecasting." Liquid helium was obtained by use of "a compressor, two gas refrigerating machines and intermediate heat exchangers; at a certain stage the cooled gas was passed through an expanding throttle valve."

26 Canadian authorities reveal that more radioactive debris – ranging from dust to small fragments – has been found at Fort Resolution, Pine Point and Hay River on south shore of Great Slave Lake.

28 Canada asks scientific sub-committee of UN Committee on the Use of Outer Space for Peaceful Purposes to establish special working group on "questions relating to the uses of nuclear power sources in outer space."

[Continued on page 191

T 2

EVA AND THE SPACE SHUTTLE

By J. E. Catchpole

Introduction

On 18 March 1965 the then totally unknown Soviet cosmonaut Alexei Leonov became the first man to leave the safety of his capsule as it orbited the Earth and 'walk' directly in the void of space. Since that day many others have followed Leonov's couragous example and such Extra-Vehicular Activity (EVA) has now become almost a routine activity.

With the advent of the Space Shuttle it can be taken for granted that EVA will have a still more distinctive role to play.

EVA is foreseen in support of many duties:

- Inspection, photography and possible manual override of spacecraft (Orbiter) and payload systems, mechanisms and components.

- Installation, removal and transfer of film cassettes, material samples, protective covers and instrumentation.

- Operation of equipment, including assembly tools, cameras and cleaning devices.

- Connection, disconnection and storage of fluid and electrical umbilicals.

- Repair, replacement, calibration, repositioning and inspection of modular equipment, antennae and instrumentation of the spacecraft or payloads [1].

The Shuttle Orbiter will always carry enough Life Supporting consumables to facilitate three EVA's. Two of these will be two-man EVA's, each lasting up to six hours, in support of the payload or spacecraft as necessary.. Consumables for the third EVA (of all crewmen) will be kept in reserve for an emergency. EVA will be the main form of rescue from an incapacitated Orbiter.

Space Shuttle Extra-Vehicular Mobility Unit (SSEMU)

A new EVA suit has been designed for the Shuttle programme and, unlike the earlier Apollo and Skylab suits, the new model will not be individually tailored to fit the wearer. The new suit comes in several sizes, each one adjustable in length and each adjustable to fit either male or female form.

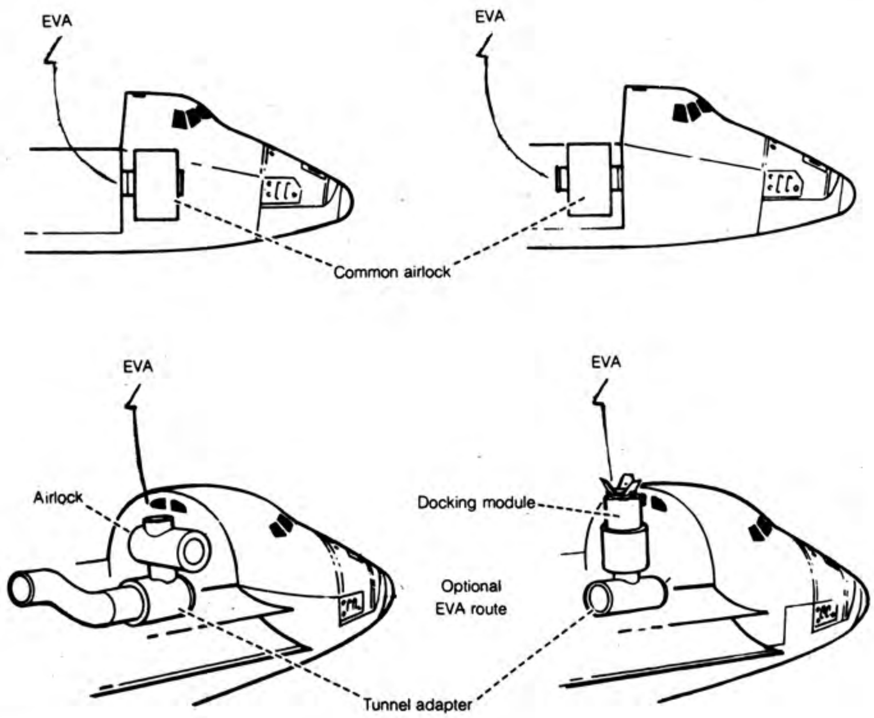
Each suit has two major sections, an *upper-torso* made of aluminium with a Portable Life Support System (PLSS) backpack permanently attached; and a *lower-torso*, or trouser section, made of fabric. The two parts are easily joined by a circumferential bearing connector around the waist. The fabric and polyurethane joints of the SSEMU allow the wearer to bend the legs and arms with less physical effort than was required to bend even the modified Apollo and Skylab EMU's. Gloves, made of Kelvar, allow the astronaut enough feeling and dexterity to handle small articles – including tools – with ease.

The SSEMU comes in three distinct parts: a water-cooled undergarment, the pressure garment and fittings, and the Life Support System.

The undergarment, worn next to the skin, contains plastic tubing through which water is passed to remove the astronaut's excess body heat.

The pressure garment, with its airtight pressure balloon and rigid upper torso, is complete with fabric trousers. Mounted in the display and control unit on the chest area of the upper torso is a microcompressor (a computer on a chip circuit) which provides instructions to the PLSS, checks-out the suit, monitors its functions, alerts the wearer if anything goes wrong and even suggests the action to be taken – all automatically. The usual communications cap, with earphones and microphone, intravehicular bubble helmet, EVA over-visor assembly, gloves, drink bag and body waste collection device complete the pressure garment.

The PLSS supplies oxygen for up to six hours plus a 30 minute emergency period. This oxygen is used for breathing, suit pressurisation and ventilation. Also included in the PLSS are a two-way radio and the water needed to



Space Shuttle Orbiter: Possible airlock arrangements.

National Aeronautics and Space Administration

cool the suit. The PLSS will also clean the suit's atmosphere of carbon dioxide and other expelled gasses.

Orbiter EVA Facilities

Each time a Shuttle Orbiter is launched it will contain all the necessary equipment and supplies for two six-hour EVA's and an emergency EVA.

The most obvious of all the Orbiter's EVA equipment will be the airlock through which the EVA party will leave and re-enter the spacecraft. The airlock can be situated in one of several places, depending on the payload carried. The usual position will be in the middle deck of the crew section with entry through the aft bulkhead; another location is outside the aft bulkhead (in the payload bay). When Spacelab is carried the airlock will be installed on the tunnel adapter. When docking is planned the docking module will be attached to the tunnel adapter and either the docking module or the tunnel adapter will provide EVA egress.

The Shuttle airlock will contain two D-shaped hatches on opposite walls of the chamber, thus allowing easy transfer of equipment through the airlock. The flat side of the D makes the minimum clearance 36 in. The inside diameter of the airlock is 63 in. and it will be 83 in. long. This volume will allow two pressure suited astronauts to transfer a package 18 x 18 x 50 in. through the airlock [2].

The Shuttle EVA suits will be carried into orbit in the airlock, hanging on the bulkhead. Once inside the airlock the astronauts will don the lower portion of their suits, crouch under the rigid upper torso and then stand up, pulling the upper half on like a sweater.

Each EVA will require three hours pre-breathing , the first two hours of which can be spent completing non-EVA tasks, the last hour preparing for the EVA.

On leaving the airlock the astronauts will find EVA handrails extending down the line of the payload door hinges into the payload bay at various points as well as on the aft bulkhead.

When Spacelab is flown the EVA astronauts will find EVA handrails extending up the forward cone, across both sides of the top and down the aft cone of any pressurised modules being carried. The Spacelab pallets have EVA handrails along the upper sills or foot restraints on the inner walls. All EVA restraints on the Spacelab pallets are installed before the Laboratory is loaded into the payload bay and may be positioned to suit the requirements of the experiments in the pallet [3].

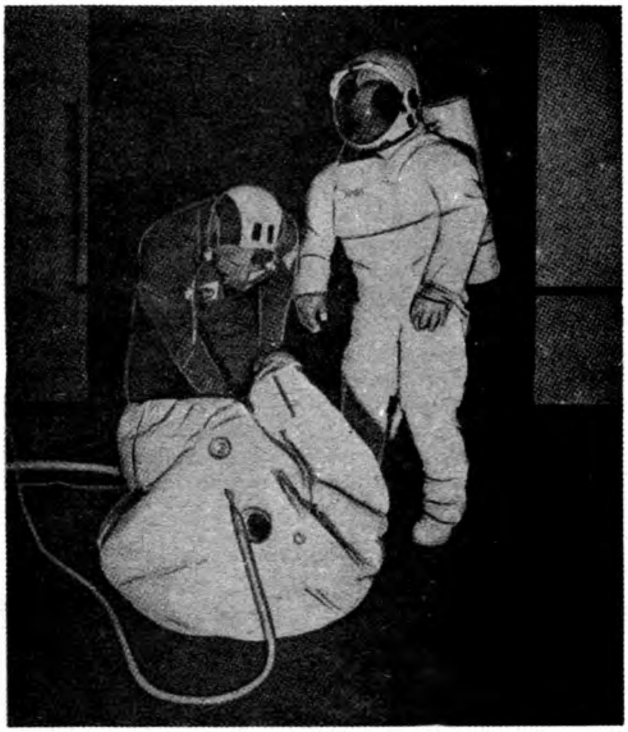
If at any time an unplanned EVA is required, where no EVA aids are installed, it is hoped that available structures will provide sufficient restraint to prevent impact with the payload.

Normally EVA will be carried out by just two astronauts – the Mission Specialist (who will be selected by NASA) and the Orbiter's Pilot. The Mission Specialist will be the prime EVA astronaut and in charge of the EVA. If however the payload requires EVA by more than two men the extra EVA suits and consumables required will be charged against the weight of the payload that requires the extra EVA astronaut.

Emergency EVA

In the case of a Shuttle Orbiter being unable to return to Earth,EVA will be the main form of rescue. Following rendezvous with the rescue vehicle the Pilot and Mission Specialist will don their EVA suits while the Commander and Payload Specialist zip themselves in a Personnel Rescue Enclosure. The Rescue Enclosure, a 34 in. diameter inflatable plastic ball, contains life-support and communication systems. The Rescue Enclosure can be transferred to the rescue vehicle by any one of the following methods:

- The on-board remote manipulator.



Shuttle EVA space suit and inflatable 'zipball' Rescue Enclosure.

National Aeronautics and Space Administration

- A device similar to the Lunar Equipment Conveyor used to transfer equipment from the Lunar Module to the lunar surface during the Apollo Moonflights.
- Being carried by the spacesuited crewmembers.

Normally two pressure suits and two Personnel Rescue Enclosures will be carried on all Orbiters with the minimum four-person crew. If more than four men make up the crew then LSS and extra Rescue Enclosures will be charged against the launch weight of the payload requiring the extra crewmen [4].

Manned Manoeuvring Unit

In 1975 the Johnson Space Center in Houston, Texas, awarded a design contract to the Martin Marietta Corporation in Denver for the conceptual design of a Space Shuttle Manned Manoeuvring Unit (MMU). The contract was a direct follow-on from the highly successful M509 manoeuvring unit tested inside the Skylab Orbital Workshop during that programme in 1973-74. Experiment M509 showed just how accurately an astronaut could control his movements in a weightless environment while enclosed in a pressure suit and strapped in a mechanical manoeuvring unit.

The new MMU, shaped like a horseshoe, is designed to fit around the EVA astronaut's PLSS which makes the unit comparatively easy to don and doff. It will be used whenever the EVA astronauts are required to reach a point on the spacecraft outside of the payload bay.

REFERENCES

1. "Space Shuttle," NASA SP-407, p. 58.
2. "Space Shuttle," NASA SP-407, p. 58.
3. "Spacelab Payload Accommodation Handbook" (Preliminary issue May 1976), pp. 3-39.
4. "NASA Facts" 79/6-77, p. 7.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

CLUE TO LIFE ON MARS?

Scientists working for NASA and the National Science Foundation have discovered living organisms hidden inside rocks in the frozen deserts of the Antarctic. The discovery – made in the Dry Valleys, a region whose harsh climate resembles conditions found on Mars – significantly extends the known limits of life on Earth, and also carries important implications for the search for extraterrestrial life.

The discovery was made by Dr. E. Imre Friedmann and Dr. Roseli Ocampo-Friedmann of Florida State University at Tallahassee, a husband-and-wife team which had been searching for microbial life in rocks for more than 15 years.

The newly-discovered microorganisms – bacteria, algae and fungi – have been isolated and are growing in laboratory cultures, where they are being studied for clues to the secret of their endurance.

The Friedmanns had found living cells inside rocks in the hot desert areas of America, Asia and Africa, but the Dry Valleys of Antarctica have long been regarded as lifeless. No plant or animal life is visible on the bare cliffs, and microbiological investigations of the soil, as well as theoretical investigations, indicated that they are lacking any native microbial life.

Although part of the "White Continent," the Dry Valleys region of the Antarctic, is generally free of snow and ice, the combination of dryness and cold, as well as the nearly constantly blowing winds, results in an environment which is among the world's harshest.

In this frozen brown desert, mountain ranges as high as 2,400 metres (8,000 ft.) alternate with valley floors, some of which contain permanently frozen lakes of high salt content.

Far from being lifeless, the Friedmanns found that the Dry Valleys have a widespread rich microbial vegetation under the surface of rocks, in the air spaces of porous rocks or in fissures.

When the rocks are broken open, the organisms are seen as a dark greenish layer, a few millimetres deep.

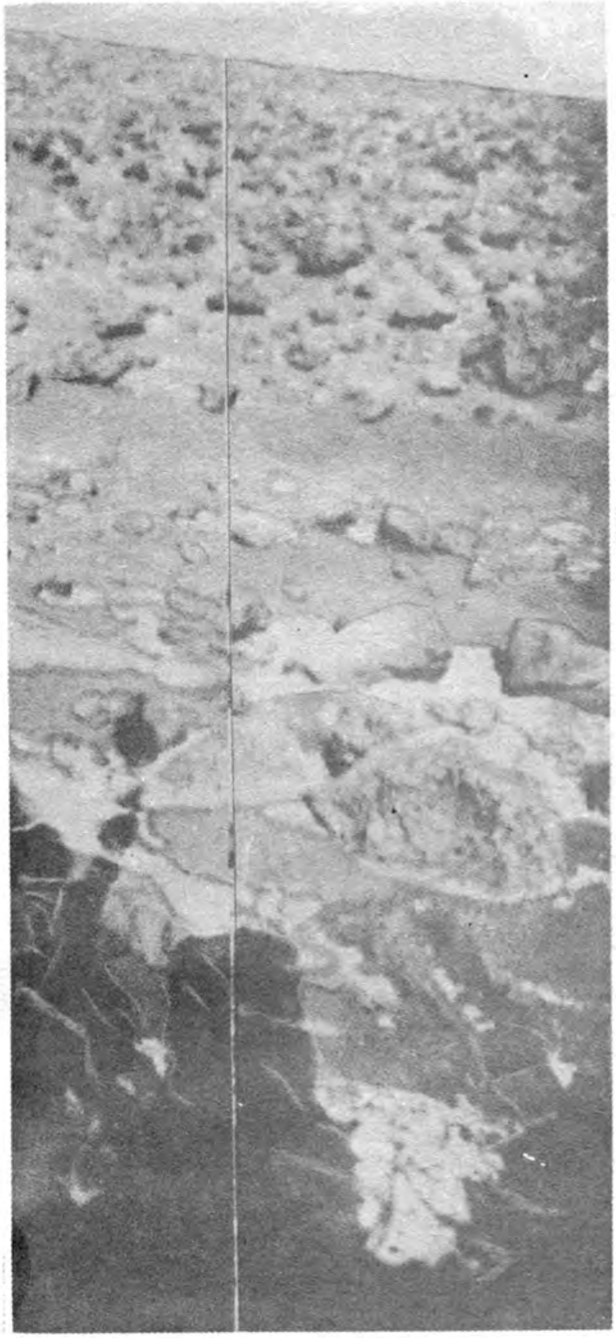
Dr. Friedmann said the tiny organisms take refuge from an unfavourable climate by occupying a microscopic niche where favourable conditions for life prevail. He points out: "The microclimate between the minute grains of the rock may be quite different from the macroclimate outside."

The organisms colonise light-coloured semi-translucent rocks in which the intensive Antarctic sunlight penetrates several millimetres deep. Thus, while the temperature outside (and on the surface of the rock) may be well below freezing, inside the rock it may rise to relatively comfortable levels.

The penetrating sunlight also provides energy for photosynthesis, while the uppermost rock layer protects the microorganisms from damage due to excessive radiation and drying up. Dr. Friedmann said that wherever the "proper" rock types occur, it is most likely that they are colonised by microbes, algae or fungi.

Dr. Richard S. Young, NASA's chief of planetary biology, points out that the Dry Valleys in many ways approach the environmental extremes found on Mars by the 1976 Viking landers. These landers searched the Martian soil for signs of microbial life and organic molecules, apparently without success.

"If Martian life forms exist only in the interior of Martian rocks, as is principally the case in the Antarctic, that could easily serve as an explanation for the lack of evidence on Mars," says Young. "Viking could not open rocks and analyse the interiors."



LATE WINTER FROST ON MARS. Viking Lander 2 picture from *Utopia Planitia.* Frost appears as a white accumulation around the bottom of rocks, in a trench dug by the sampler arm, and in scattered patches on the reddish-brown surface. The frost was on the ground for some time and disappeared over many days, suggesting that it is not frozen carbon dioxide (dry ice) but it is more likely to be carbon dioxide clathrate (six parts water and one part CO_2).

National Aeronautics and Space Administration

Young continues: "This interesting (if speculative) analogy is of considerable interest to NASA in designing future attempts to study planetary surfaces for evidence of life.

"If under these conditions of environment life is most likely to reside in the interiors of certain rock types, the design of the spacecraft would be influenced accordingly. For example, we would search out specific rock types and design a sampler which can open rocks and provide sub-surface samples which can be examined for life forms and organic molecules. This would lead to quite a different mission sequence than was done in Viking."

Dr. Friedmann expects that studies of the newly-discovered life forms now under way will yield further information on their distribution and way of life. The Friedmanns' work was supported by research grants provided by NASA and NSF.

PRESIDENT CARTER'S SCIENCE BUDGET

An eleven per cent increase in scientific research funds with emphasis on climatic studies highlighted President Carter's budget request of 28,000 million dollars for federal support of research and development.

"There is a definite tilt in the budget to basic research," said Dr. Frank Press. The President's science advisor Dr. Press stressed that the budget reflected the President's pledge in his State of the Union address to "maintain America's leadership role in science and technology." The 3,600 million dollars requested solely for basic research will affect all science, writes USIS Science Correspondent Everly Driscoll.

Of the total recommended, Mr. Carter requested 104 million dollars for intensified investigation of Earth's climate. The National Oceanic and Atmospheric Administration (NOAA) would coordinate research in eight federal agencies. Scientists would like to be able to predict not only changes in the climate, but what effects such changes will have on agricultural prices and energy consumption. Research will be directed toward these goals and toward theory that can predict changes to climate caused by man-made alterations of the land and pollution to the atmosphere.

Besides the four different kinds of weather and atmospheric satellites now in space, two more would be developed in the Carter plan. The first would determine how the Earth uses the energy it receives from the Sun: what amount is lost back to space and how much is stored in the atmosphere and oceans. The second satellite would measure chemical interactions between sunlight, ozone (a form of oxygen in the atmosphere that blocks lethal solar radiation) and man-made chemicals. Funds would also be increased for study of clues to Earth's past climate, which are found in deep-sea drill core samples and tree rings.

Basic research, conducted and funded by 10 major federal agencies, was increased across the board. That included a nine per cent increase for government support of university research and development. Of the total 28,000 million dollars recommended, 3,600 million dollars would go to universities. "The funds are intended to encourage innovative research and to assist in ameliorating some of the problems currently associated with the performance of research in colleges and universities, such as the growing obsolescence of equipment and the lack of opportunities for young investigators," Dr. Press said.

Besides the Department of Defense, for which President Carter requested an 8.8 per cent increase in research and development funds, the largest increases were recommended for the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and the Department of Health, Education and Welfare (HEW).

The NSF's budget, with a recommended 10 per cent increase for basic research, would continue support of oceanography, astronomy, mathematics, physics, the computer sciences and engineering, as well as research not funded by other agencies, such as the study of materials that could be substituted for rare metals. Funding for earthquake-related research initiated in 1977 would be increased as part of a coordinated programme with the US Geological Survey. NSF will continue climate studies, but will increase grant money to study Earth's carbon dioxide cycle. Construction will continue on the large radio telescope in New Mexico that will pinpoint and observe distant galactic radio signals.

Mr. Carter sought more than eight per cent increases to NASA's budget including a 27 per cent increase for space science. Construction of four Space Shuttle Orbiters, the key element in the new US Space Transportation System, was sought, as was continued construction of Shuttle launch facilities at Vandenberg Air Force Base in California, and Cape Canaveral in Florida.

Besides the new weather-related satellites, NASA would begin development of a spacecraft to fly over the poles of the Sun, an unknown region of the Solar System. The polar flight would take spacecraft out of the plane of the ecliptic, the region through which most planets orbit.

NASA would also continue development of a Large Optical Telescope in space and development of experiments for use in the European Spacelab that will fly inside the Shuttle Orbiter. Funds were also requested for continued operation of two Viking orbiters and two landers on Mars, for exploration of the planet Venus in December 1978, for operation of two Voyager spacecraft *en route* to Jupiter, and to launch a spacecraft to monitor world-wide pollution. NASA's aeronautical research funds were also increased by 16 per cent.

The four per cent increase Mr. Carter recommended for new research would be spent primarily at the National Cancer Institute and the National Heart, Lung and Blood Institute to study genetics, immunology, virology and cell biology. Major increases were earmarked for biomedical and behavioural research on human reproduction and family planning and in biology and child development.

A special grant programme begun in 1977 to encourage innovative plant research outside the department of agriculture would be doubled from 15 million to 30 million dollars. Competitive grants would be awarded for research on methods to increase the yield of crops, to improve plant resistance to drought and pests, and for investigations into energy-saving techniques for agriculture.

The President called for continued construction of a powerful new particle accelerator for high-energy physics concerned with the properties of energy and matter, and construction of a facility to produce high-intensity uranium beams for nuclear physicists studying the properties and dynamics of atomic nuclei.

While Mr. Carter's recommendations for research and development funds for the Department of Energy would increase by only three-tenths of one per cent, his reductions in funds for demonstration projects would allow substantial increases.

The Carter Budget recommended increases of 23 per cent in research funds for production of electricity by solar energy, and 18 per cent increase for fusion research, a 23 per cent increase for geothermal research and a 27 per cent increase for basic energy research.

Funds saved by cancelling the plutonium-producing breeder reactor at Clinch River, Tennessee, would be spent on research for alternative approaches to nuclear reactors and on alternatives to recycling fuels that would present less risk of international proliferation of nuclear weapons than does the use of separated plutonium.

"HOT LINE" VIA SPACE

The Washington-Moscow hot line, which has been in use since 1963 as a direct means of communication between the heads of state of the United States and the Soviet Union, has now entered the "space age."

On 16 January 1978, the US-USSR hot line began using two independent satellite systems to transmit messages between the American and Soviet capitals, writes USIS Special Correspondent Norbert Yasharoff.

The new line, officially named Direct Communications Link, or DCL, is expected to provide communications service of higher reliability than the existing cable link and the recently discontinued high-frequency radio system. Incorporating the many technological advances of satellite communications, the DCL is less vulnerable than the present system since it depends to a lesser degree on extensive terrestrial microwave or cable relays and eliminates dependence on third-country facilities. In addition, the DCL is not susceptible to interruptions caused by atmospheric interference problems common to high-frequency radio systems.

From its inception the hot line has been designed for use during periods of increased international tension or emergency. Its main purpose is to serve as a direct, private communications link between the President of the United States and the President of the Soviet Union.

The DCL, like its predecessor, and contrary to widespread public belief, makes possible the exchange of printed messages and not telephone calls. Printed messages have the advantage of overcoming language barriers, avoiding possible misunderstanding by translators, and providing a written record of the exchanged communications.

Hot line teletype messages from the United States to the Soviet Union are transmitted in the English language, using the Latin alaphabet. Messages from the Soviet Union are transmitted to the United States in the Russian language, using cyrillic characters. All messages, including transmission tests, are automatically encoded upon transmission and decoded upon receipt. Circuits are tested hourly, using a variety of sample "messages." Normally, items such as non political passages from magazine articles and books are used in the text of test messages.

The two DCL satellite systems employ the Soviet "Molniya" and the commercial "Intelsat" satellites. Both systems operate simultaneously so that if one system fails, the other continues to provide communications.

In the "Molniya" system, there are four satellites which operate in highly elliptical, inclined orbits. Each satellite is used for approximately six hours a day as the satellites sequentially come within the view of both the US and USSR Earth stations.

In the "Intelsat" system, on the other hand, coverage is obtained from a single satellite positioned in a geo-stationary orbit 22,300 miles (35,680 km) over the mid-Atlantic at the equator.

Within the United States, there are two satellite Earth stations associated with the DCL. One of them, the "Molniya" Earth station, is located at Fort Detrick, Maryland, and operates – under the supervision of the US Army Communications Command – twin 60-ft. (18-metre) satellite antennae for use with the "Molniya" satellites.

The second US Earth station, located at Etam, West Virginia, is a commercial facility, which has a satellite ground terminal using the "Intelsat" satellite. It is operated by the Communications Satellite Corporation (COMSAT).

In the Soviet Union, two "Molniya" Earth stations serving the DCL are located near Moscow. Two "Intelsat" Earth stations, a primary and a backup station for the DCL, are located at Lvov and Moscow.

The need for a Washington-Moscow hot line as a means of reducing the risk of intentional or accidental nuclear confrontation was first recognised in the late 1950's. In the Fall of 1962, the Cuban missile crisis further underscored the critical need for a direct line of communication between the American and Soviets Heads of States.

After the missile crisis subsided, both the United States and the Soviet Union moved toward the establishment of a hot line as a matter of utmost priority. The original Washington-Moscow hot line was subsequently inaugurated on 30 August 1963, and has been in operation ever since.

During its more than 14 years of existence, the most notable use of the hot line occurred during the Arab-Israeli Six-Day War in 1967 when President Johnson advised the Soviet Union of US ship and aircraft movements in the Mediterranean following an Israeli attack on the *USS Liberty*.

The new US-USSR hot line is a result of the first phase of the Strategic Arms Limitation Talks (SALT) between the two countries. In September 1971, as part of the initial SALT negotiations, the United States and the Soviet Union agreed to improve the reliability of the hot line linking Washington and Moscow by using modern satellite communications technology.

Through a series of technical discussions, the new satellite system was engineered, resulting in a "Molniya" Earth station being constructed in the United States and two "Intelsat" Earth stations being built in the Soviet Union.

SPACE AIDS GLAUCOMA SURGERY

As regular readers of *Spaceflight* will already be aware the bounty of Space bursts around us constantly like tiny gushers, often in quite unsuspected directions. None are more welcomed than the 'gushers' which spin off in the direction of medicine and surgery.

The latest example – a new device to reduce and regulate pressure inside the eye during glaucoma surgery – has been developed by NASA's Lewis Research Center in Cleveland, Ohio, and the Kresge Eye Institute in Detroit.

The new system which provides continuous recording of pressure inside the eye during surgery is based on fluid systems and components technology developed by the National Aeronautics and Space Administration (NASA).

Glaucoma, characterised by elevated pressure inside the eye, occurs widely throughout the world and medical treatment to reduce and control it is not always successful. In such cases, surgery may be used to relieve the pressure.

The pressure reduction system mechanically lowers the intraocular pressure – pressure inside the eye – to any level desired by the physician over a set time and in a controlled manner. The system has a number of apparent potential uses. It may be most immediately useful in dealing with those glaucomas in which intraocular pressure remains markedly elevated in spite of medical treatment immediately prior to glaucoma surgery.

The pressure regulator is designed to maintain a set minimum pressure inside the eye within a reasonable range during glaucoma surgery. The device has accomplished this.

A fluid supply, whose pressure has been matched to the existing intraocular pressure, is connected to the anterior (front) chamber of the eye through a very small tube inserted near the edge of the cornea. Pressure of the fluid supply is reduced in a controlled fashion and in such a way that the intraocular pressure is reduced by the same amount and at the same rate.

The pressure regulator part of the system is a flow-compensating device that adjusts automatically to maintain the set minimum intraocular pressure after the eye has been opened by surgical penetration during the glaucoma surgical procedure. If only very small liquid flows are expected during the surgery and after surgical penetration of the eye,

intraocular pressure can be established and maintained by adjusting pressure of the fluid supply alone and the pressure regulator need not be a part of the system.

Investigations with the system have shown that intraocular pressure excursion peaks resulting from external loads such as surgical manipulation are reduced if the interior eye resting pressure is first lowered. Such reduction of the peak pressures is to be expected and might have been predicted. Use of this new system, however, reduces such intraocular pressure excursion peaks even further because the penetrating tube becomes a pressure relief mechanism.

The technique will permit investigating, and may also be instrumental in reducing, some post eye surgery complications such as cataract formation, vascular membrane detachment, flat anterior chamber and malignant glaucoma. Further development of the device will be continued under controlled clinical conditions.

The equipment was developed by the Lewis Center and Cleveland ophthalmologist Dr. William J. McGannon and Dr. Dong H. Shin of Kresge Eye Institute, Wayne State University, Detroit.

GALILEO PROBES JUPITER

In a grand gesture to history the National Aeronautics and Space Administration has announced that the ambitious 1982 mission to place an orbiting spacecraft around Jupiter and send a probe into its atmosphere will be named Project Galileo.

Scheduled to become the first planetary spacecraft to be carried aboard NASA's Space Shuttle, Galileo will conduct the most detailed scientific investigation yet of Jupiter, its environment and moons, including the first direct measurements of the planet's atmosphere.

The mission is composed of an orbiter which will circle the planet for at least 20 months and a probe which will plunge deeply into Jupiter's atmosphere (see cover, *Spaceflight*, October 1977). The orbiter will carry 10 instruments, and the probe will carry six.

Galileo is the first planetary spacecraft to be named for a person, although NASA's Orbiting Astronomical Observatory 3 (OAO-3) was christened Copernicus after it was launched in 1972.

Peering through the newly-invented telescope, Galileo Galilei in January, 1610, was the first to see the four larger moons of Jupiter, although he did not immediately recognise them as such. The satellites, known as the Galilean moons, are named Io, Europa, Ganymede and Callisto, after four lovers of the god Jupiter (Zeus) in Greek mythology. These are the satellites which will be closely investigated by the orbiter during the Galileo mission.

In March 1610, Galileo published the *Starry Messenger*, which announced the discovery of many stars, markings on the surface of the Moon and the satellites of Jupiter. This was the first scientific publication written in lay language. The publication made Galileo famous, popularised the science of astronomy and established a firm support for the Copernican (Sun-centred) theory of the motion of the planets.

SOLAR ARRAY CONTRACT

A lightweight solar array that could be used for a direct broadcast television satellite in the mid-1980's is the subject of a £311,000 contract received by British Aerospace Dynamics Group from the European Space Agency. The contract reflects Britain's growing expertise in this important field.

The 20-month contract covers a comprehensive development programme for a hybrid array, that is an array with two solar panels, one of which supplies power during the transfer orbit of the satellite, and continues in geostationary orbit to supplement the power of the much larger deployable array.

Dynamics Group are responsible for the array's overall system design, manufacture and test and the Royal Aircraft Establishment at Farnborough are to provide technical assistance. AEG/Telefunken under contract to British Aerospace will be responsible for design of the solar blanket.

The Bristol factory has specialised in power supplies for space applications since the early Seventies having built solar arrays or structures for the global series of communication satellites Intelsat IV and IVA, the COMSTAR United States 'domestic' satellites and scientific satellites Ariel 3 and 4, and UK6, the technology satellite Prospero X-3 and the cosmic ray satellite COS-B. In addition to development work on a flexible roll-up array, solar cell interconnections, hybrid structures and mechanisms, British Aerospace has recently been awarded a £6 million contract by the European Space Agency to develop and build the solar array for NASA's Space Telescope.

HANDHELD X-RAY DEVICE

A concept fostered by a NASA scientist for studying X-ray sources in space has led to a handheld X-ray instrument which produces an instant image with a small source of radioactive material. Powered by a single pen size battery, the prototype model of the rugged device exhibits high potential for screening and other uses in medicine, dentistry and areas of industry. The most obvious promise of the unique unit is for emergency and other field use where a quick fluoroscopic examination is desirable.

The new device, developed by Dr. Lo I. Yin, and X-ray research at NASA's Goddard Space Flight Center, is called a Lixiscope (for Low Intensity X-ray Imaging Scope). It is based on a concept under study to research energy sources in space by converting their X-rays to visible images.

"The concept was not feasible until the declassification of an image intensifier developed by the Army's Night Vision Laboratory at Ft. Belvoir, Virginia," Dr. Yin said.

"The Lixiscope has a variety of potential applications, including patient screening, root canal analysis and possibly the monitoring of surgical procedures," said Dr. Richard Webber, Chief of the Clinical Investigations Branch of the National Institute of Dental Research (NIDR).

Researchers at NIDR already have designed one configuration of the new device to be tested for dental application. Other researchers at Howard University's Cancer Research Center would like to compare the Lixiscope with existing X-ray techniques for preliminary screening of soft tissue tumors.

EUROSATELLITE

A subsidiary company called Eurosatellite is being set up by Aérospatiale (France), Messerschmitt-Bölkow-Blohm (West Germany) and Etca (Belgium) to promote applications satellites, particularly for telecommunications. The company will concentrate on developing external markets for satellite systems particularly in developing countries such as Indonesia, Iran, India, Brazil and the Arab League.

Eurosatellite will be a limited-liability company under German law with headquarters in Munich. Aérospatiale and M-B-B each have a 43 per cent interest and Ecta 14 per cent.

THE SHUTTLE ASTRONAUTS

NASA Administrator, Dr. Robert A. Frosch, has announced the selection of 35 new astronaut candidates for the Space Shuttle programme. This group of candidates will report to Johnson Space Center, Houston, Texas, on 1 July 1978. There they will join the astronauts currently on flight status.

The newly selected candidates include 14 civilians and 21 military officers. Of the group, six are women, and four are minorities. There are currently 27 astronauts on active status (17 pilots and 10 scientist astronauts) and one on leave of absence.

In making the announcement, Dr. Frosch said: "The long and difficult task of selecting the most qualified candidates for the Space Shuttle programme has been concluded and we are very pleased with the results. We have selected an outstanding group of women and men who represent the most competent, talented and experienced people available to us today."

NASA received 8,079 applications during a year-long recruiting period which ended on 30 June 1977. Since August, 208 finalists have been interviewed and have undergone medical examinations at NASA's Johnson Space Center

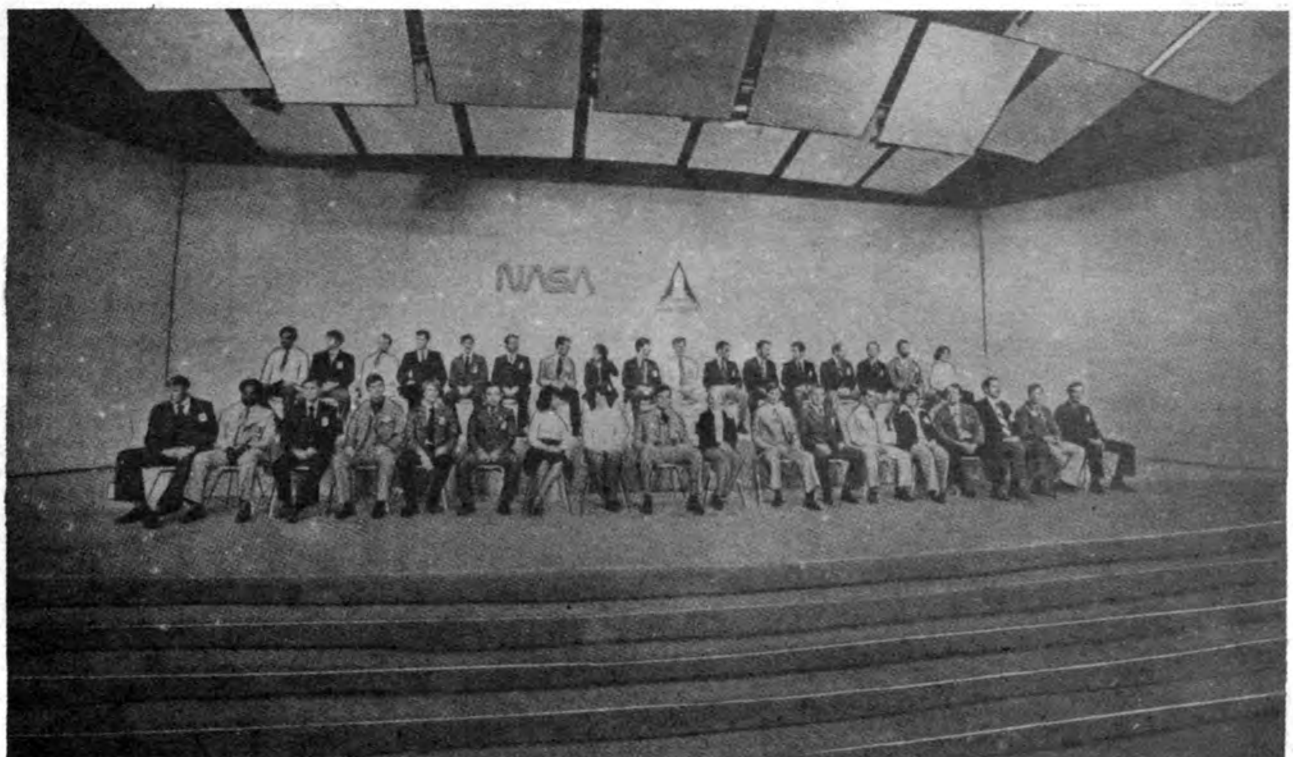
After two years of training and evaluation at the Johnson Space Center, successful candidates will become astronauts and enter the Shuttle training programme leading to selection on a Space Shuttle flight crew.

Pilots will operate the Space Shuttle Orbiter, manoeuvring it in Earth orbit and flying it to Earth for a runway landing.

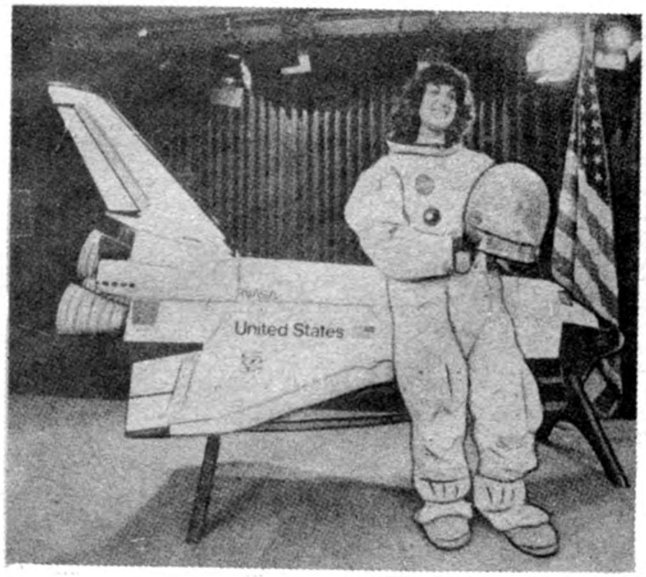
Mission specialist astronauts will have overall responsibility for the coordination, with the commander and pilot, of Space Shuttle operations in the areas of crew activity planning, consumables usage, and other Space Shuttle activities affecting experiment operations. They may participate in extravehicular activities (space walks), perform special payload handling or maintenance operations using the Space Shuttle remote manipulator system, and assist in specific experiment operation at the discretion of the experiment sponsor.

Bluford, Guion S.	US Air Force	Mission Specialist
Brandenstein, Daniel C.	US Navy	Pilot
Buchli, James F.	US Marine Corps.	Mission Specialist
Coats, Michael L.	US Navy	Pilot
Covey, Richard O.	US Air Force	Pilot
Creighton, John O.	US Navy	Pilot
Fabian, John M.	US Air Force	Mission Specialist
Fisher, Anna L.	Civilian	Mission Specialist
Gardner, Dale A.	US Navy	Mission Specialist
Gibson, Robert L.	US Navy	Pilot
Gregory, Frederick D.	US Air Force	Pilot
Griggs, Stanley D.	Civilian	Pilot
Hart, Terry J.	Civilian	Mission Specialist
Hauck, Frederick H.	US Navy	Pilot
Hawley, Steven A.	Civilian	Mission Specialist
Hoffman, Jeffrey A.	Civilian	Mission Specialist
Lucid, Shannon W.	Civilian	Mission Specialist
McBride, Jon A.	US Navy	Pilot
McNair, Ronald E.	Civilian	Mission Specialist
Mullane, Richard M.	US Air Force	Mission Specialist
Nagel, Steven R.	US Air Force	Pilot
Nelson, George D.	Civilian	Mission Specialist
Onizuka, Ellison S.	US Air Force	Mission Specialist
Resnik, Judith A.	Civilian	Mission Specialist
Ride, Sally K.	Civilian	Mission Specialist
Scobee, Francis R.	US Air Force	Pilot
Seddon, Margaret R.	Civilian	Mission Specialist
Shaw, Brewster R., Jr.	US Air Force	Pilot
Shriver, Loren J.	US Air Force	Pilot
Stewart, Robert L.	US Army	Mission Specialist
Sullivan, Kathryn D.	Civilian	Mission Specialist
Thagard, Norman E.	Civilian	Mission Specialist
van Hoften, James D.	Civilian	Mission Specialist
Walker, David M.	US Navy	Pilot
Williams, Donald E.	US Navy	Pilot

Below. the group of 35 astronauts at Johnson Space Center seated in alphabetical order, second row, left to right, Bluford to Lucid; first row, McBride to Williams.

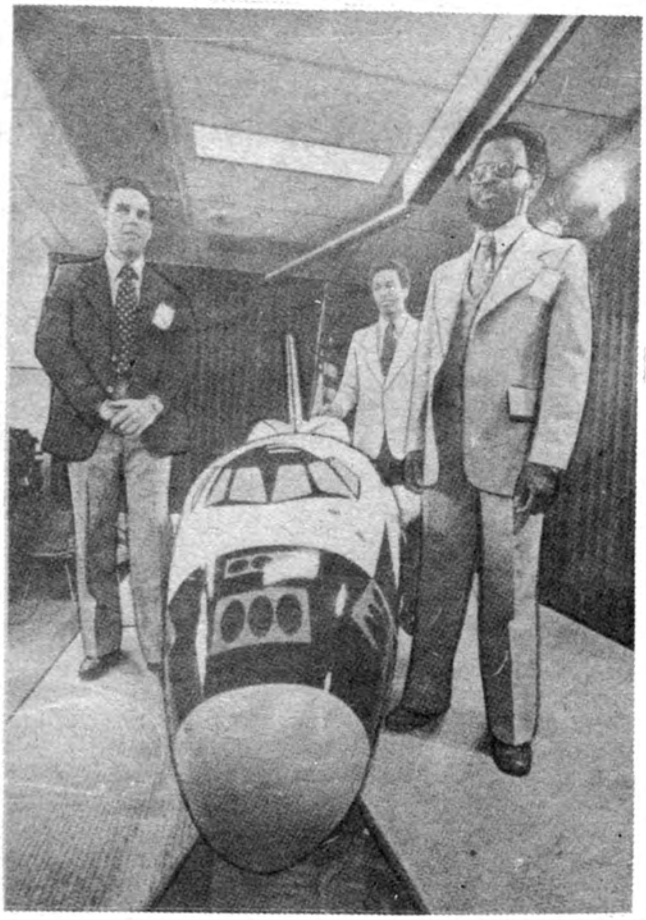


The six girls: left to right, Margaret Rhea Seddon, Anna L. Fisher, Judith A. Resnik, Shannon W. Lucid, Sally K. Ride and Kathryn D. Sullivan.



Dr. Judith A. Resnik in spacesuit.

All photos: Annie M. Tiziou/JTNS



Left to right, Major Frederick D. Gregory; Major Guion S. Bluford, Jr., and Dr. Ronald E. McNair.

NASA'S 25 LAUNCHES IN 1978

The National Aeronautics and Space Administration has scheduled 25 launches this year, 15 of which will be for paying customers. The customers include the European Space Agency (ESA), Comsat Corporation, the US Navy, Japan, the National Oceanic and Atmospheric Administration (NOAA), the United Kingdom and Canada.

Last year 12 of the 16 NASA launches were in this category most of them emphasising the use of space for the direct benefit of people on Earth with such applications as communications, geodesy, navigation, meteorology and study of the Earth's environment and resources.

In planetary research,1977 was the year of the Voyagers which are heading out on Grand Tours passing Jupiter and Saturn. This year the quest returns to Venus which is to receive two Pioneer spacecraft.

Pioneer Venus-A is scheduled to be launched by an Atlas-Centaur in May with the intention of placing a spacecraft in orbit round the planet to examine its upper atmosphere. Pioneer Venus-B, to be launched by another Atlas-Centaur in August, is scheduled to enter the Venerian atmosphere six days after the Orbiter arrives. The spin-stabilised multi-probe spacecraft consists of a 'bus', a large probe and three identical small probes, each with scientific instruments.

The probes will be released from the 'bus' 20 days prior to arrival at Venus. The large probe will conduct sounding of Venus' lower atmosphere, measuring clouds as well as atmospheric structure and composition. The smaller probes, entering at widely separated points, will provide information on the general circulation patterns of the lower atmosphere.

The Table gives a full rundown of the various satellite and probe missions scheduled in 1978:

Date	Payload	Launch Vehicle	Launch Site	Reimbursable	Remarks
Jan. 6	Intelsat IV-A (F3)	Atlas Centaur	KSC	Yes	Communications satellite for Comsat Corporation.
Jan. 19	FLTSATCOM-A	Atlas Centaur	KSC	Yes	Fleet Satellite Communications for Navy.
Jan 25.	IUE-A	Delta	KSC	No	International Ultraviolet Explorer, space science.
February	Intelsat IV-A (F6)	Atlas Centaur	KSC	Yes	Communications satellite for Comsat Corporation.
March 5	Landsat-C	Delta	WTR	No	Polar-orbital ecological data satellite.
March 23	Japan/BSE	Delta	KSC	Yes	Experimental broadcasting satellite for Japan.
April	HCMM	Scout	WTR	No	Heat Capacity Mapping Mission to produce thermal maps of atmosphere.
April	Comstar-C	Atlas Centaur	KSC	Yes	Third in a series of domestic communications satellites.
April	OTS-BU	Delta	KSC	Yes	European Space Agency Orbital Test Satellite.
May	GEOS-C	Delta	KSC	Yes	Geostationary Environmental Satellite for Earth imaging.
May	TIROS-N	Atlas-F	WTR	No	Polar orbiting weather spacecraft, operational.
May	Pioneer Venus-A	Atlas Centaur	KSC	No	Planetary Mission to Venus, studies of solar wind.
May	Seasat-A	Atlas-F	WTR	No	Sea satellite for global ocean monitoring.
June	ESA/GEOS-B	Delta	KSC	Yes	ESA spacecraft to study atmospheric radiation particles.
June	Japan/BU	Delta	KSC	Yes	Backup satellite for Japan.
July	UK-6	Scout	Wallops	Yes	United Kingdom satellite to measure radiation particles.
July	ISEE-C	Delta	KSC	No	International Sun Earth Explorer to work with A and B missions.
August	Nimbus-G	Delta	WTR	No	Weather and oceanographic satellite.
August	Pioneer Venus-B	Atlas Centaur	KSC	No	Venus multiprobe mission to study planet's atmosphere.
September	Navy-20	Scout	WTR	Yes	Navy navigation satellite, call-up.
September	NATO-III-C	Delta	KSC	Yes	NATO communications satellite, second in series.
October	HEAO-B	Atlas Centaur	KSC	No	Second High Energy Astronomical Observatory to study space radiation.
November	Telesat-D	Delta	KSC	Yes	Canadian domestic communications satellite.
November	FLTSATCOM-B	Atlas Centaur	KSC	Yes	Fleet Satellite Communications for Navy (second).

PROBLEMS OF SPACE DEBRIS

American engineers will attempt during the next few months to manoeuvre the 77-ton Skylab space station into a flight mode that would delay its predicted 1979 re-entry into the Earth's atmosphere, writes USIS Science Correspondent, Everly Driscoll.

Such a delay would provide time needed to ready Space Shuttle astronauts for a rendezvous with Skylab in October 1979. The astronauts would attach to the station's docking port a rocket engine to boost the Lab to a higher orbit where it would safely remain for ten years.

Skylab is the largest of 4,692 Earth-orbiting objects that include 928 satellites, other broken-up satellites and debris. Skylab carries no radioactive power station such as the one aboard the Soviet Cosmos 954 that re-entered the atmosphere on 24 January, scattering debris over a remote region of Canada.

Nevertheless, Skylab's re-entry has been a major concern of the National Aeronautics and Space Administration ever since the Lab was launched in 1973. Predictions at that time, however, indicated that the Lab would remain in a higher, safe orbit well into the 1980's, providing time for corrective manoeuvres to be carried out by Shuttle astronauts. Not included in those predictions, however, were effects of sunspot and solar-flare activity on Earth's upper atmosphere. This activity has changed the air density, increased the drag exerted on the Lab and has accelerated the Lab's descent toward Earth.

NASA now hopes to slow that rate of descent with a manoevure scheduled for later this year. But the delaying tactic is complicated and any number of things could prevent its completion.

Flight controllers at Houston's L. B. Johnson Space Center must first communicate with Skylab and command its batteries to recharge with energy from sunlight collected by the solar panel. The communications attempt may not succeed; or the solar panel may have deteriorated since its use in 1974. If the recharging operation is completed, engineers can then command the firing of rocket jets that will cause the Lab to tumble slowly end-over-end.

Such a tumble will decrease the amount of gravitational drag on the Lab. Without the tumble, gravity will continue pulling Skylab Earthward where in 14 to 18 months it will re-enter the atmosphere, burn and break up into hundreds of pieces, some of which will hit Earth's surface somewhere along a path 160 km wide and 4,000 km long.

Since 1957, 5,700 space objects have re-entered the atmosphere and burned up. Several hundred pieces of debris have hit the surface; none have resulted in personal injury or damage claims. The largest piece from the US space programme, a Skylab rocket stage larger than the Lab, re-entered in January 1975 and fell into the Atlantic Ocean.

Not related to Skylab but of public concern nonetheless are satellites powered by radioactive materials that could one day fall back to Earth. Two types of radioactive power stations – one active and one passive – have been used either in the US or Soviet Union space programmes. The active kind is similar to the reactor that powered Cosmos 954. As in most nuclear power stations on Earth, these reactors use uranium in a chain reaction which fissions atoms, producing energy and harmful gamma radiation.

Only one US satellite with such a reactor on board has ever been launched; that occurred in 1965 and the satellite has since been boosted to a very high orbit where it will remain for 4,000 years. According to US sources, all Soviet satellites using reactors also have been boosted to higher orbits – except when the apparent failure of the booster engine caused the re-entry of Cosmos 954.

The second class radioactive power station, and the one used operationally in the US space programme, is a passive unit (not a reactor) called the radio-isotope thermal electric generator, or RTG. These units contain plutonium which decays naturally, giving off heat that is converted to electricity. During the Apollo programme, astronauts on the Moon handled RTG's; using tongs, they removed the units from a compartment on the Lunar Module and inserted them into a central station that powered scientifc instruments.

At present, the United States has eight satellites powered by RTG's in Earth orbit, six in deep space and five on the Moon. The eight are a NASA Nimbus weather satellite, five Navy navigational satellites and two communications satellites.

All of the RTG's are encased in graphite, designed to withstand the heat of re-entry and bring them to Earth intact should the satellites re-enter the atmosphere. None are expected to re-enter for years, well beyond the time when the plutonium, with a half-life of 88 years, is exhausted.

Three RTG's have, in fact, survived re-entry in each case on aborted satellites or spacecraft. Two units powered a Nimbus satellite that fell into the Santa Barbara Channel off the West coast of the United States. The RTG's were recovered undamaged from the ocean. The third was on the aborted Apollo 13 Lunar Module that fell into the South Pacific.

Before the change in design which insures the RTG's would survive re-entry, the RTG's were designed to burn up in the atmosphere. In 1964, a satellite with an RTG did re-enter and burn up.

All the rest of the orbiting US satellites are powered by solar energy.

But spacecraft sent to planets at great distances from the Sun use RTG's for power. The two Pioneer spacecraft that flew by Jupiter in 1973 and 1974 respectively both have RTG's on board. One Pioneer is on a path that will take it out of the Solar System; the second will fly by Saturn in 1979. The two Viking Landers on Mars are powered by RTG's as are the two Voyager spacecraft *en route* to Jupiter.

COSMOS 954 INCIDENT

Three days after the Soviet nuclear-powered satellite Cosmos 954 disintegrated over the North-Western Territories of Canada on 24 January, President Carter gave an interview with the editors of the American Press Institute. The following excerpts are from the transcript of that interview:

Question: Mr. President, now that the reactor from the Soviet satellite has been found in Canada and found to be highly radioactive, what is your Administration planning to do to prevent such mishaps, satellite mishaps, from occurring again and also what are your plans for a stop in the nuclear proliferation in space?

The President: I had breakfast this morning with Secretary Vance and Dr. Brzezinski and this is one of the subjects that was discussed.

As you know, we have a long standing treaty with the Soviet Union preventing any atomic explosions in space. But we were guilty of that a long time ago. I think it is time to re-examine that question. I believe that this recent incident with the Soviet satellite has shown that we don't have an adequate guarantee safety requirement on nuclear fuel in space.

This particular satellite and all that we have ever launched – I think the first one we put up using nuclear power was in 1965 – have what is called a sub-critical mass. There is not enough radioactivity there to cause an explosion under any circumstances, but as and when the satellite is first launched, it is relatively clean. You could probably get close to it with-

out having radiation. The longer it burns, the more by-products are made and the more radioactivity is likely to come.

This particular satellite was designed, as are most of them, to be elevated into that higher orbit when it had served its purpose. When the Soviets attempted to elevate it into a higher orbit, which would have kept it in space for a thousand years or more, some mechanism failed. I don't know the details of it. But I think that we now are in the process of deciding what we can do to minimise this danger from space.

One possibility would be to design such a nuclear power plant, which is very small, so that it would surely burn completely as it came down through space itself by increasing the drag or friction, and so forth.

Another one would be to have standby mechanisms so that if the first one failed to eject it into outer orbit, another standby would be required. This is something that we have not yet gone into in any definitive way.

We have a much higher reliance, as you may know, on solar panel power supplies and we do not rely on the atomic power supplies as much. But you have a good question, and it is something that we have not yet addressed with the Soviets, but I am sure it is something that we will address.

Question: Mr. President, are you satisfied with the response of the Soviets when you asked for information about the satellite that was burned?

The President: That is hard to say. We had discovered that the satellite was having a problem back in December. I don't remember the exact day.

I made the decision myself to contact the Soviets. We told them we were aware of the problem, asked them for any information about the satellite and told them unofficially that we would not try to capitalise on their misfortune in a propaganda way.

We wanted to be sure that the adequate preparation was made for the re-entry of the satellite into the atmosphere and we notified some of our key allies around the world who would have the capability both to monitor the progress of the satellite and also to deal with the radioactivity once it fell.

I had a difficult decision to make in how much publicity to bring to this satellite because it is almost impossible to let people know the facts without the threat of being exaggerated.

We didn't want to create exaggerated fears. We monitored the satellite constantly. We shared with the Soviets estimates of when it would come down. The exact point of the penetration of the atmosphere was not known until just an hour or two before it crashed because it was tumbling. And when a satellite of that kind enters the atmosphere, it can skip off and go several thousands of miles further than you have actually anticipated.

We knew that it would fall somewhere between just north of Hawaii, north-east of Hawaii, or the eastern side of Africa. And it was making a great circle route up above the point where it finally fell. That was just about the northern point.

The Soviets did tell us in general what kind of reactor it was. They told us that their best estimate was it would burn as it entered the atmosphere.

So I can't without going back and checking the exact language of their report to us; I can't say whether they gave us all the facts. But I think it was handled properly; certainly by us.

I don't know who else the Soviets notified. When I found it was going to hit Canada early that morning – I come over here quite early in the morning – I called the Prime Minister of Canada and talked to him on the phone.

We were pretty lucky in telling him where it was going into the atmosphere. We had it on radar. But in retrospect, it may be that the Soviets could have given us more information. I think they probably gave us about what we would have given them under a similar circumstance.

LEONID SEDOV ON COSMOS 954

The end of Cosmos 954 over northern Canada did not create any danger for the population of the area. Nor was there any danger to people during other emergency falls of satellites with nuclear power units on board.

This was the opinion of Academician Leonid Sedov in a *Tass* interview published on 4 February.

Academician Sedov emphasised that Cosmos 954's small nuclear reactor containing Uranium-235 was designed to ensure its destruction and burning up on entry into the dense layers of the atmosphere. It was not in any way explosive.

He declared that the absurdity of statements which appeared to pretend that Cosmos 954 was almost a flying nuclear bomb should be obvious. There had even been allegations that the nuclear unit had been designed to power a laser gun. There were not, and could not be, any weapons on board the satellite, stressed Academician Sedov, for the Soviet Union strictly observed the 1967 treaty on the use of outer space which bans the orbiting of any objects with nuclear weapons or any other types of weapons of mass destruction.

It was necessary to use nuclear power because it was the most effective power source for long-duration flights and was quite within international law, having been used on more than one occasion by both the USA and the USSR. All the necessary measures are taken to ensure radiation safety both in normal and emergency conditions. This was the case with Cosmos 954.

The origin of Cosmos 954's erratic behaviour was not definitely known since it was beyond the range of Soviet tracking equipment. But on 6 January Cosmos 954 suffered a sudden depressurisation causing the on board system to go out of operation and the satellite to begin its "uncontrollable descent."

It may be assumed, said Academician Sedov, that the satellite collided in flight with some other object of natural or artificial origin. Great efforts were made to determine in what area the satellite would be likely to descend, in order, if it was over some foreign country, to notify that country in advance.

It was calculated that Cosmos 954 would cease to exist over the sea near the Aleutian Islands on 24 January and the US government was notified accordingly.

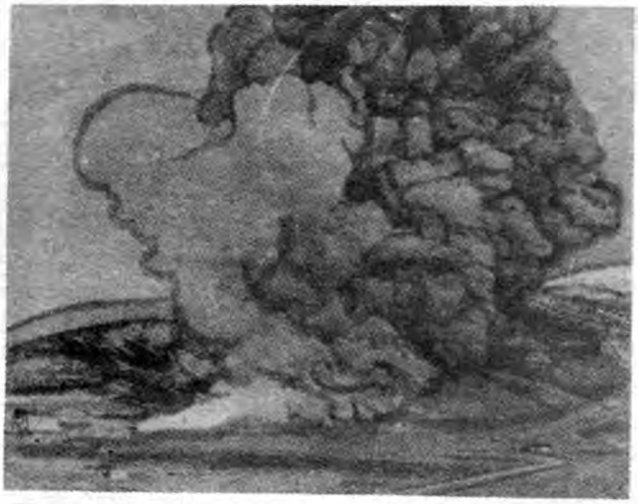
Immediately it was learnt that the satellite ceased to exist over northern Canada, the Soviet government offered urgent assistance in "eliminating the consequences of a possible fall of individual parts of the satellite on Canadian territory and evacuating them." Information on the satellite and its power unit was passed to the Canadian government.

If any objects suspected of being part of the satellite were found, the Soviet government offered to send Soviet specialists to identify them.

Academician Sedov went on to remark that Soviet specialists are not aware of the results of the search. Nor do they possess information on observations of Cosmos 954 as it passed through the dense layers of the atmosphere.

SRB FIRES AGAIN

A huge solid rocket motor, being developed for Space Shuttle flights beginning in 1979, roared to life in the Utah desert in January successfully passing its second full-duration ground static firing development test. Thiokol Corporation's



SOLID ROCKET MOTOR being developed for the NASA Space Shuttle during the second full-duration static test on 18 January 1978.

Thiokol Corporation

Wasatch Division, prime contractor for development of the motor for NASA's Marshall Space Flight Center, Huntsville, Alabama, conducted the firing at a test fixture near Brigham City, Utah.

Tied to the test fixture, the 125-ft. long (38.1 metre) motor fired for slightly over two minutes reaching a thrust level of 2,832,000 lb. (12,596,736 Newtons).

Engineers termed the test highly successful, advancing the motor further along toward flight readiness. The motor is slightly over 12 ft. (3.65 metres) in diameter. During the firing, 1,102,400 lb. (500,048 kg) of propellants were burned.

The motor nozzle was gimballed early in the test and again later in the firing. The duration of the gimballing equalled about half the total burn time. During Shuttle launches the Solid Rocket Booster's motor nozzles will gimbal to help provide directional control for the entire Shuttle assembly.

The next development test of the motor is scheduled this summer.

ATLAS-CENTAUR FAILURE

A NASA Board of Inquiry has issued its final report on the failure of an Atlas-Centaur launch vehicle which occurred on 29 September 1977. Launched from the Kennedy Space Center, Florida, the vehicle with an Intelsat IV-A spacecraft aboard was destroyed 55 seconds into the flight.

The Board of Inquiry determined that the cause of the Atlas-Centaur failure was a rupture in the high pressure "omega joint" in the Atlas stage booster gas generator discharge line. The fault occurred as a result of corrosion following contamination during brazing in the production cycle.

Since the fault was a processing failure, not a design problem, the joints on all other completed vehicles were tested. All vehicles now at the Kennedy Center passed the test, but a few omega joints in the factory were corroded or questionable, and are being replaced.

In the future, fabrication of this joint and others like it using the same stainless material will be processed in a manner which prevents contamination.

SETI AND ASTRONOMY

There is a 50 per cent chance that within the next 22 years astronomers will intercept radio signals from intelligent life outside the Solar System, according to Cornell astronomer Frank Drake, Director of the world's most powerful radio telescope in Arecibo, Puerto Rico.

The chances are greater – almost 100 per cent – of detecting Jupiter-sized planets orbiting some of the 400 stars within 30 light-years distance of Earth, Dr. Drake said at the annual conference of The American Association for the Advancement of Science (AAAS).

"We are now developing instruments that can address these two fundamental issues," he said. Several sessions of the meeting concerned Earth and space-based tools, either planned for development or recently activated, that will permit investigations of hitherto unanswerable questions. Among them are questions about the universality of the laws of physics, the products of Cosmic evolution, and the nature of newly discovered objects such as quasars and pulsars, and the possible discovery of black holes. But the most fundamental are questions of extraterrestrial life.

Requested in President Carter's 1979 fiscal year budget to Congress were 2.1 million dollars for development of a million-channel radio receiver for intercepting possible radio beams from galactic civilization. Included as part of the search for extraterrestrial intelligence, or SETI programme, the funds would formally initiate the project within the National Aeronautics and Space Administration, writes USIS Correspondent, Everly Driscoll.

Astronomers have long argued that the surest way of detecting galactic life is through the interception of radio signals that travel at the speed of light. The signals could be intentionally sent by other civilizations, such as the message beamed from Arecibo in 1974 to Messier 13, a cluster of 300,000 stars near the boundary of our Milky Way Galaxy. Or the signals intercepted could be from planetary leakage, the accumulated noise that constantly escapes a planet on which radios are used for communication.

Astronomers have undertaken sky searches, pointing radio receivers tuned to a certain frequency to one, then another, of hundreds of nearby stars. This frequency-by-frequency search will be greatly enhanced if the million-channel receiver is approved, Dr. Drake said.

Eventually receivers much larger than even the 300-metre-diameter Arecibo dish will be needed, Dr. Drake said. It is not enough just to detect the existence of other life. "We are going to need big receivers to find out what they know, to tap our cosmic heritage."

Related to this search for extraterrestrial intelligence is the search for planets orbiting other stars. Astronomers traditionally have done this by tracking stars year after year, searching their paths for perturbations (wobbles) created by the gravitational pull of accompanying planets. Barnard's star, 5.6 light years from Earth, appears to 'wobble' as though it might have one or more orbiting planets the size of Jupiter. But a more direct approach will soon be available with the 2.4 metre space telescope, to be placed into Earth orbit around 1983 with the Space Shuttle system. With it, astronomers will be able to see planets around nearby stars.

Several ground-based telescopes now under construction will aid in resolution capacities of radio and optical telescopes of Earth. In Arizona in the southwest United States, there will be a cluster of 27 individual 25-metre radio antennae that together form a "Y," with each leg of the "Y" 20 kilometres long. The whole system will be steered as a unit, focused on distant radio sources. A similar approach will be tested in the neighbouring State of New Mexico with an array of optical telescopes, called the Multiple Mirror Telescope. The collection would be equivalent to a single mirror 4.5 metres in diameter.

Dr. Drake's personal optimism about the chances of finding life, and planets that support it, is based on these new tools that are making the previously invisible – and unheard – universe known.

"Historically," said Dr. Drake, "astronomers have not been able to study many of the fundamental questions because, as an observational science, astronomy was forced to study those things that could be observed." New tools are changing this, plus "an army of highly-trained, young, vigorous astronomers. Ninety per cent of all astronomers who have lived are alive today," he said. (There are about 6,000 astronomers world-wide; 3,000 alone are in the United States).

Finally, new astronomical tools are making it possible to detect a dynamic, explosive and turbulent universe only dimly perceived prior to the Space Age: the invisible universe permeated with powerful X-ray radiation. Were this energy converted to visible light, the whole night sky would glow as bright as the full Moon.

A special session of the AAAS meeting was devoted to presentations of first results from HEAO 1 the High Energy Astronomical Observatory, launched in August of 1977. Its instruments are surveying the sky for X-ray sources. Dr. Herbert Friedman of the US Naval Observatory noted that prior to 1948 no X-ray sources were known. Then the Sun's X-rays were observed with instruments aboard V-2 rockets. By 1962 the first galactic source of X-ray radiation had been discovered. With the launch of the Uhuru satellite in 1970, 200 stars or objects emitting X-rays were mapped. Now, with the High Energy Astronomical Observatory, the count has risen to 1,000.

Nuclear explosions on a star are responsible for some X-ray emissions. But astronomers now believe another process also results in X-rays: the activity of a black hole. Black holes are believed to be collapsed stars – stars that have fallen in on themselves due to enormous gravitational pull of their mass after their nuclear furnaces have been spent. This gravity first breaks the atomic barrier by forcing electrons into protons to create neutrons – or a neutron star called a pulsar. But in a black hole the collapse continues, creating matter that could be similar to that which existed moments after the Universe was created some 15,000 million years ago. The black hole emits no energy and thus, by itself, could not be detected. But a curious discovery is that many X-ray sources (and potential black holes) are part of two-star systems – one star close to another. In most cases, one is a visible star. But as the black hole collapses it draws in all surrounding matter, including matter from the normal star. As matter is sucked to the black hole, it is accelerated to high energies and temperatures and emits X-rays.

HEAO has also observed objects that emit X-rays like a machine gun, bursting hundreds of times a minute.

Two more HEAO's will be launched, one in November of 1978 and another in August of 1979.

SALYUT 'SPACE FACTORY'

First reports of the 'space factory' experiments performed by Lt. Col. Yuri Romanenko and Georgi Grechko aboard the Salyut 6/Soyuz 27 space station are encouraging. The main object was to gain an understanding of welding and soldering in space and the possibility of creating new composite materials, writes Kenneth Gatland.

Soviet scientists have been talking of applying new composite materials produced under micro-gravity conditions in future spacecraft structures. They aim to expand the research programme in the years ahead.

Before Romanenko and Grechko could begin their experiments, they had to assemble the 'Splav' electric furnace in an airlock on the side of the station. (When installed the rear end of the furnace faces outer space). They had also to install a control panel, connect plugs and sockets and set up cameras and recording instruments.

All the smelting equipment had been ferried to them in the unmanned cargo ship Progress 1 which docked on 22 January.

Furnace temperatures, which can exceed 1,000°C, are computer-controlled within an accuracy of five degrees.

The first experiment was carried out to study diffusion processes in molten metals under weightlessness. The cosmonauts placed capsules containing copper-indium, aluminium-magnesium and indium-antimonide into the furnace and depressurised the airlock. The heating elements were then switched on and a preset programme ensured optimum temperatures during the process of crystallisation.

The second experiment employed as research materials aluminium-tungsten, molybdenum-gallium and a semi-conductor. The compounds of the pairs of metals obtained in the experiment were later to be studied on Earth "to discover the interaction of solid and liquid metals in weightlessness."

During the experiments the space station complex was allowed to drift with its attitude control system switched off to reduce the influence of disturbing forces.

NEW ASTEROID FAMILY?

Professor Charles Kowal of the California Institiute of Technology recently announced the discovery of a new member of the Solar System. Newspapers reported the discovery of "a tenth planet," but the reality may be much more interesting.

The object, provisionally named Chiron, orbits between Saturn and Uranus in an orbit whose elements more closely resemble the ellipse of comets according to Dr. Brian Marsden. This controversy indicates the need for further study since the first plates of Chiron showed little more than a blurred smudge, writes A. T. Lawton. However, the recent discovery of faint rings around Uranus – these rings being composed of small bodies up to 100 km in diameter – supports the hypothesis that there are several small dark bodies moving in the outer regions of the Solar System.

The actual diameter of Chiron itself is uncertain for it depends on a reliable estimate of the albedo (reflection factor) of the surface material. If this was similar to water ice or snow then the body would be approximately 100 km in diameter. Since it is more likely to be covered with darker material in similar fashion to Phobos, then it could be much larger, possibly 800 km in diameter. If Chiron does prove to be the first of a newly discovered familty of asteroids whose main characteristic is low reflectivity then further support is given to the agglomeration-condensation theories of Solar System formation. This demands that water separates out closer to the Sun than the orbit of Chiron, leaving behind more complex hydrocarbon volatiles which condense in the outer regions. The solid hydrocarbon is darker than normal ice. Since these complex hydrocarbons are believed to be an essential factor in the formation of proteins leading to living cells, it is quite possible that on Chiron and similar bodies will be found the deep frozen store of part of our 'Genesis.'

A future visit to such a body could well provide vital clues in our search for the origins of life.

NEXT MONTH. Scheduled is a major feature, 'Switchboard in the Sky,' by S. W. Fordyce, L. Jaffe and E. C. Hamilton, which describes the vast potential market that is opening in the field of satellite communications. Also in this issue: 'Soviet Atmospheric and Surface Venus Probes.'

INFRARED ASTRONOMICAL SATELLITE

By W. I. McLaughlin* and W. H. de Leeuw†

Introduction

A significant gap in the electromagnetic spectrum between the visible region and radio waves will be filled by the observing programme of the newly approved Infrared Astronomical Satellite (IRAS).

Early in 1981 a satellite instrumented with a 60 cm infrared telescope will be put into a 900 km near-polar orbit from the Western Test Range in California. IRAS, the result of a cooperative affort among the United States, the Netherlands, and the United Kingdom, will conduct an all-sky survey in the infrared without hindrance from the extensive absorption and emission of the atmosphere.

The sensitivity may be as much as 1,000 times greater than previous work from the ground and rocket flights (e.g., see [1] and [2]) and could increase the number of known infrared sources from about 6,000 to 1,000,000.

Infrared telescopes require a cold environment in order to detect signals above the thermal noise of the system. IRAS will carry a cryogenic system containing liquid helium (LHe) which maintains the infrared detector array in the focal plane at about 3°K throughout the nominal one year lifetime of the mission. In fact, this lifetime is determined by the length of time it takes the initial 100 kg of the LHe to boil off into space.

The satellite will collect about 7×10^8 bits of data per day. Twice each day, during passes over the tracking station in England, the contents of the tape recorder will be transmitted at a rate of one megabit per second. At the same time the satellite's observational plan for the next twelve hours is sent up. A portion of the data returned to the ground will be examined immediately by the IRAS ground operations team to develop information which may be used to optimize subsequent observational plans. The full data set will be communicated to the Jet Propulsion Laboratory (JPL) for more extensive processing. This may result in further modifications to the observing programme and will be processed into a set of final data products, including an infrared catalogue, summarising the identifications provided by the mission activity.

A more detailed description of the IRAS project is contained in [3].

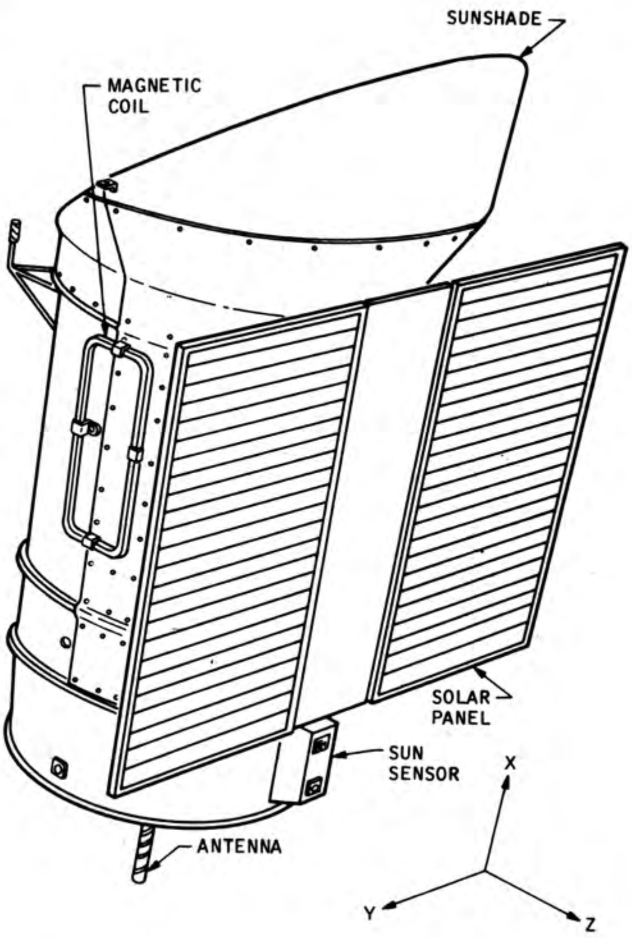


Fig. 1. Exterior view of Infrared Astronomical Satellite.

All illustrations JPL, National Aeronautics and Space Administration

Project Organisation

The satellite consists of a spacecraft and telescope. The spacecraft supplies necessary support, such as electrical power and pointing control, to the telescope during flight operations.

The Netherlands is responsible for the design and manufacture of the spacecraft. The Netherlands Aerospace Agency (NIVR) is supervising this task which is executed by an industrial consortium (ICIRAS) consisting of Fokker-VFW and Hollandse Signaalapparaten.

The United States is responsible for the construction of the telescope, the processing of the experimental data to produce the final IR catalogue, and the launch vehicle. JPL manages the project for NASA's Office of Space Science and will perform the data processing. The Ames Research Center has responsibility for the telescope system, and the Delta Project Office at the Goddard Space Flight Center provides launch facilities and support.

The United Kingdom, with funding through the Science Research Council, will provide satellite tracking and other ground support. The control centre will be located at the Appleton Laboratory in Slough with computing support from the Rutherford Laboratories near Oxford. The tracking station will be located at the Winkfield facility. Ground operations in the UK are cordinated by the Dutch National Aerospace Laboratory under subcontract from ICIRAS.

This multinational effort requires close coordination among all the agencies involved in IRAS. In addition to a continuing exchange of information relevant to the satellite development, quarterly meetings among the project elements are held alternately in Europe and the United States.

Mission Geometry

The nominal orbital elements for IRAS are:

altitude = 900 km

eccentricity = 0

inclination = 99°

longitude of ascending node = right ascension of mean sun minus 90°

These orbital elements yield a period of about 103 minutes which results in close to 14 satellite revolutions per day.

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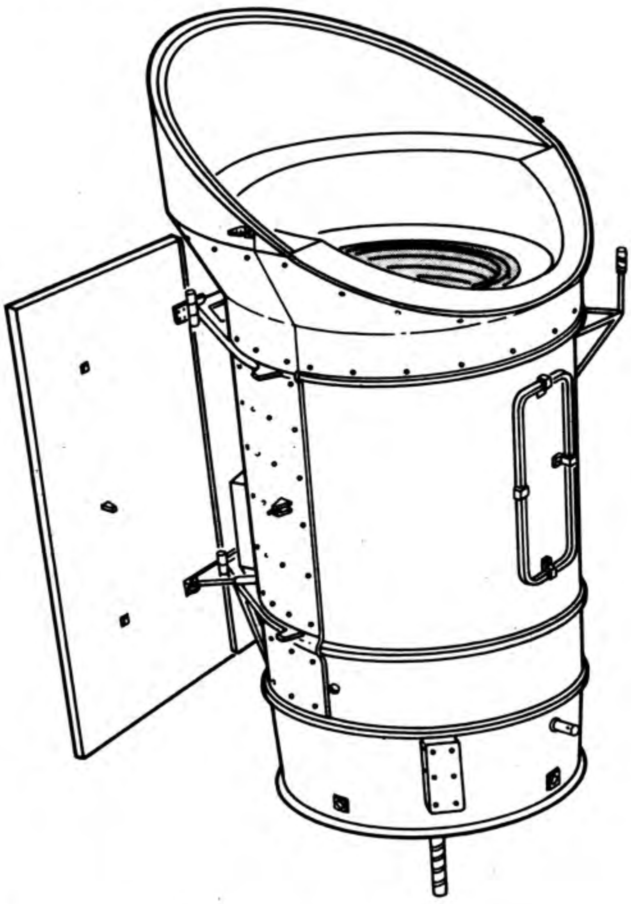

Fig. 2 Exterior view of IAS (rear view).

As with most astronomical satellites, high precision in the orbital parameters is not essential so that no capability for adjusting the orbit is included in the satellite. Similarly, only that determination of the orbit which is sufficiently accurate to provide adequate predictions of station passes is required. Hence, the sole type of tracking data that will be used is angular measurement.

The 900 km altitude was chosen as a compromise between possible contamination of the instrument by atmospheric constituents at lower altitudes and excessive radiation hits by protons at higher altitudes in the Van Allen belts. The eccentricity is close to zero because a non-circular orbit presents no advantages and complicates station-pass planning. At an altitude of 900 km and an inclination of 99° the oblateness of the Earth advances the orbital plane of the satellite at the same rate as the motion of the mean Sun, i.e., the orbit is Sun-synchronous. The longitude of the ascending node is selected to place the Sun-to-satellite line as close to perpendicularity with the orbital plane as possible.

This relationship between the location of the Sun and the line of nodes of the orbital plane of the satellite maximises the area of the sky to which the telescope can point without encountering thermal overload problems due to radiation from the Sun and Earth. A solar constraint on pointing limits the angle between the telescope optical axis and the Sun to no less than 60°, and the Earth thermal load on the aperture limits the angle between the telescope optical axis and the local vertical to no more than 30°. Thus, at those times of year when the Sun is perpendicular to the orbital plane the telescope can be pointed within the range of 60° (solar constraint) to 120° (Earth constraint) from the Sun. At other times, the upper bound on this range is reduced.

These pointing limits have been obtained by the design of the Sun shade shown in Figs. 1 and 2.

A telescope pointing strategy that is being considered for the mission is based geometrically upon the set of right-circular cones centred about the (current) Earth-Sun line. Specification of the strategy consists of selecting a time-ordered series of these cones and scanning along appropriate portions of them with the telescope at a constant celestial rate. The resulting arcs on the celestial sphere are, very nearly, minor circles centred about the Sun's position. Of course, availability of any portion of a conical scanning surface is contingent upon pointing constraints due to Sun and Earth thermal loads through the telescope aperture.

It is anticipated that about 60% of the available observing time will be devoted to completion of the sky survey, which is the primary objective of the mission, and 40% will be available for special observing programmes. However, the actual allocation of time will be determined by the project's completeness and reliability requirements which control the quality of the sky survey. These requirements state that the catalogue shall contain 98% of all real IR sources above the sensitivity threshold of the survey, and no more than 0.2% of the catalogued objects shall be "false" IR sources, such as asteroids or data artifacts.

Predictable obstacles to the sky survey are high energy protons which will interrupt data collection during passage of the satellite through the South Atlantic Anomaly, and stray light from the Moon when the telescope is pointing to within about 20° of that body. However, these causes will only affect about 5% of the observing time.

Contamination of the data by the presence of non-astronomical sources such as dust, meteoroids, and artificial satellites is minimised by planned redundancy in the observing programme; each area of the sky will be observed at least six times during the life of the mission. In this way moving or spurious sources can be excluded and the reliability requirement satisfied.

An illustration of the discrimination between moving and fixed sources if given in Fig. 3. A Monte Carlo study yielded this plot of the apparent motion of over 300 typical asteroids in one IRAS orbital period *versus* the angle between the telescope's axis and the Earth-to-Sun line. The resulting correlation between apparent motion of the aster-

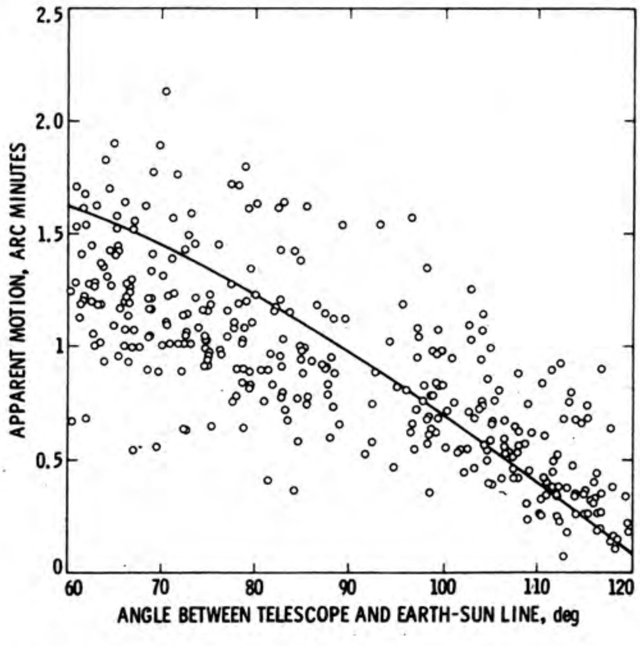

Fig. 3. Apparent motion of asteroids in one satellite revolution.

oids and the pointing angle of the telescope results from the relative motions of Earth and asteroid. If all of the asteroids were located at their mean distance of 2.8 a.u. and moved in circular orbits in the ecliptic then the functional relation between motion and geometry would be given by the solid line in Fig. 3.

It can be seen that 50% of the asteroids in this study appear to move less than 1.0 arc minutes in one orbital period and therefore it may be difficult to distinguish this class from fixed sources, due to positional uncertainties which are of this magnitude. This percentage of "frozen" asteroids can be reduced by allowing more than one orbital period to elapse before re-scanning a portion of the sky.

Satellite Description

The total weight of the satellite is approximately 990 kg, consisting of the 290 kg spacecraft and the 700 kg telescope. This is well under the 1078 kg that a Delta 2910 launch vehicle can put into a 900 km, near-polar orbit. The satellite dimensions are about three and one half metres in length by two metres in diameter.

A. *Spacecraft*

The spacecraft for IRAS is conceptually derived from the Astronomical Netherlands Satellite (ANS) project [4, 5].

Spacecraft power is obtained from a 4.5 m^2 array of solar panels. Nickel-cadmium batteries are used for energy storage during launch, initial Sun acquisition, and during eclipses which can occur for a maximum of 15 minutes per orbital period, late in the mission.

Three geometrical requirements pertaining to the survey scans determine the posture of the attitude control system: (1) the angle θ between the Sun and optical axis of the telescope should be held constant during a scan (the Sun's position is located by six coarse Sun sensors and one two-axis fine Sun sensor); (2) the scan rate across the celestial sphere must be a constant, nominally 3.85 arc minutes per second, and (3) the stars must always cross the focal plane (see Fig. 5) at right angles; thus the detector leading edges must be parallel to the Z-axis. These conditions imply that the Y-axis must be held perpendicular to the Sun line and that instantaneous rotation about the Z-axis must be at the rate of 3.85 arc minutes per second.

In addition to the Sun sensors there are three other types of attitude sensing devices; star crossing sensors, an Earth horizon sensor, and a three-axis magnetometer. The star sensors are located in the focal plane of the telescope and provide high accuracy star timings which, when compared with predicted detections, allow an update of the estimated pointing direction. The Earth horizon sensor is primarily a safety device, preventing thermal radiation from the Earth from entering the telescope aperture and overloading the cryogen system. The magnetometer senses the local direction of the Earth's magnetic field in order to determine which of three magnetic coils should be used to transfer accumulated angular momentum from the reaction wheels, which are used as the actuators for the control system, to the Earth using the Earth's magnetic field as agent.

Two other observational modes are also possible with this attitude control system: pointing and raster scan. The (fixed) pointing mode permits detailed observation of faint objects for almost 10 minutes until satellite revolution takes them from the allowable pointing region. The raster scan mode can be used to produce detailed maps of selected areas or to determine brightness contours of extended astronomical sources.

The spacecraft attitude control system is designed with sufficient precision to contribute no more than 20 arc seconds to the total uncertainty in the pointing reconstruction.

The satellite's observing programme and housekeeping chores are guided by two on-board computers (one in cold standby) which share a 64,000 word solid state memory.

Data obtained from the observing programme are stored on one of two tape recorders, each of which is capable of holding 4.5 x 10^8 bits.

B. *Telescope*

The relationship of the telescope to the spacecraft is shown in Fig. 4.

The astronomical sources move from the top to the bottom of the focal plane (Fig. 5) due to the scanning motion of the telescope. The arrangement of the detectors is such that each source encounters two detectors in each of the wavelength bands, producing a characteristic "double hump" signature for a point source in each channel. The granularity of the focal plane, resulting from detectors which are of considerably more than diffraction limited size in the cross-scan direction, contributes an uncertainty in positional estimates which is about equal to that arising from pointing reconstruction uncertainties. The total uncertainty in catalogued positions will range from about 30 arc seconds to 1 arc minute, increasing with wavelengths, with 95% confidence.

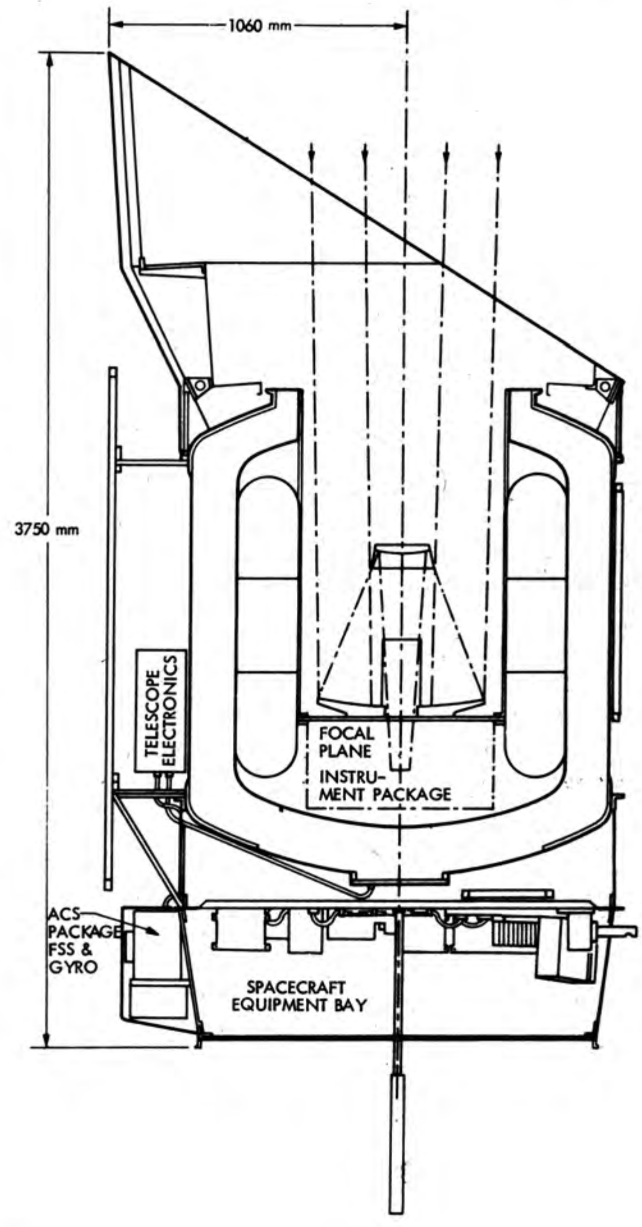

Fig. 4. Cross sectional view of satellite.

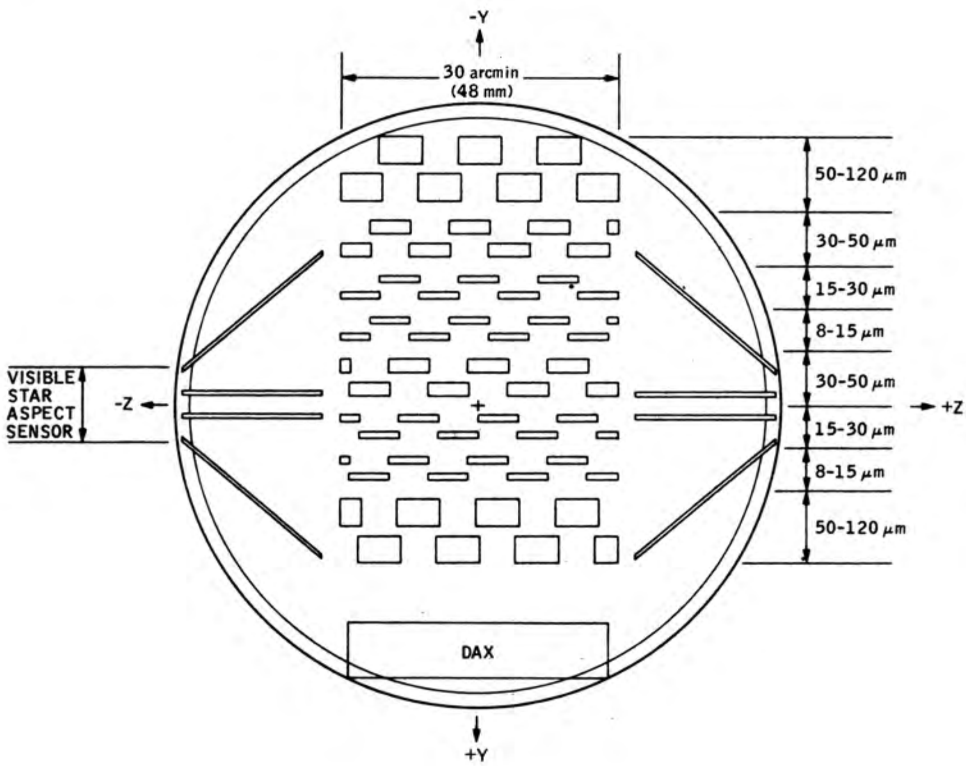

Fig. 5. Focal plane design.

The location of the Dutch Additional Experiment (DAX), a low resolution spectrometer, is also indicated in Fig. 5. The star sensors, whose function is indicated in the spacecraft description, also contain slits in a skewed position so that the cross-scan location of stars passing over them can be determined as well as the in-scan location.

The Infrared Sky

Our current knowledge of the Universe as seen in the infrared has been obtained mostly through ground-based observations and rocket flights above the atmosphere. This knowledge has been conveniently summarised in Allen's book [6], the first synoptic view of infrared astronomy. Also, a preview of some results to be expected by satellite is given in [7].

The types of objects to be observed and a brief description of the opportunities and problems they create are presented. The relevant categories are: stars, extended sources, asteroids, zodiacal light, artificial satellites, high energy protons, and dust. The properties of these objects as they pertain to the mission are simulated in an IR sky model which is implemented on the computer and used as input to a model of the telescope.

Stars and extended sources are the objects whose properties are to be extracted from the data by the project Scientific Data Analysis System. The signature of a point (stellar) source is determined by the telescope's scan rate and the detector geometry. Thus, a statistical technique such as cross correlation of the data with point-source templates can be used for the identification of stars. Extended sources, e.g., nebulae or galaxies, on the other hand, can be of a more diverse appearance. Extended objects of up to one degree in extent will be detectable. Also, the integrated background due to unresolvable stars will be particularly noticeable near the galactic equator and will itself constitute a large and bright extended source.

The orbital elements of about 2,000 asteroids have been determined with sufficient accuracy for recover upon search [8]. Extrapolating the size distribution and temperature properties of known asteroids has led to the estimate that 50,000 asteroids may be detected by IRAS. However, the satellite system itself cannot determine the orbital elements of these bodies. They will be distinguished from stellar sources by their motion as previously discussed.

Comets will not be observed in significant numbers and in any case should resemble asteroids in their kinematic properties. Meteoroids near the telescope will be detected and their rapid velocity will produce a characteristic signature in the data.

Zodiacal light provides a limiting background level that not even astronomical satellites can avoid.

There are about 4,000 artificial satellites in orbit and the apogees of perhaps half of them are above 900 km. They will be automatically screened from the data stream by virtue of their motion.

Protons trapped in the Earth's magnetic field will cause excess detector noise when the flux of 50 MeV or more energetic particles exceeds 1,000 per cm^2 per sec. This is expected to occur about 3% of the time: during passage through the South Atlantic Anomaly or during a solar flare of high intensity (such flares occur on the average of once a year or less and would interrupt data collection for less than a day). The flux of electrons does not pose a problem because the telescope is shielded from this source of interference.

Dust from the environment or contaminants carried up into orbit on the satellite are not expected to be troublesome, although such particles would be a nuisance if present in sufficient quantities. Satellite cleanliness techniques will minimise contaminant dust.

Identification of astronomical sources will be particularly difficult when the telescope points into the region near the galactic equator. The large number of stars in this area will confuse the detection algorithms and only the very brightest stars will be extracted.

The final data product, an IR catalogue of the whole sky,

will be delivered to the National Space Science Data Center at the Goddard Space Flight Center sometime in 1982 at the completion of the project.

Acknowledgements

The contribution of the first author presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under Contract No. NAS 7-100, sponsored by the National Aeronautics and Space Administration.

The contribution of the second author is based on the results of a definition study [3] executed by ICIRAS under contract from the Netherlands Aerospace Agency.

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MILESTONES/ *Continued from page 161]*

March

1 At ESA Council Meeting in Paris approval is given for go-ahead of Phase 3 of the European Communications Satellite (ECS) and second Marots commercial maritime satellite. Decision on initial funding of first six operational Ariane launch vehicles is postponed until next Council Meeting, scheduled 6-7 April.

2 Russia launches Soyuz 28 from Tyuratam cosmodrome at 18 hr. 28 min. (Moscow time). After trajectory correction orbit parameters were 269 x 309 km x 51.6 deg inclination; period 90 min. Crew comprises Col. Alexei Gubarev, 49, and Czech research cosmonaut Capt. Vladimir Remek, 29, first person other than a Russian or an American to fly in space. *Tass* reports that the Czech cosmonaut is a military pilot who had enrolled at the Soviet cosmonaut training centre in 1976.

2 Academician Yevgeni Velikov is elected Vice-President of USSR Academy of Sciences in Moscow. The 43-year old scientist is noted for his research in plasma physics and is also a recognised authority on thermonuclear synthesis.

3 Soyuz 28 docks with Salyut 6/Soyuz 27 complex at 20 hr. 10 min. (Moscow time).

4 Salyut 6 cosmonauts Yuri Romanenko and Georgi Grechko break America's 84-day world record for manned space flight at 2.36 a.m. GMT. Previous record of 2017 hr. 15 min. 32 sec. was set by third Skylab crew in 1974. "In traditional fashion, the toasts were drunk in cherry juice," says *Novosti.*

7 *Novosti* reports that main experiment undertaken by Capt. Remek aboard Salyut 6 is Czechoslovakian technology experiment called "Morava.' "Conducted in Czech-designed apparatus, it is considered an important link in the advanced quest for new materials and alloys for optical electronics... This two-day investigation of smelting under weightless conditions is expected to have given the materials qualities different or even impossible to obtain under terrestrial conditions." The main experiment was made in the Splav-01 furnace and Vladimir Remek was responsible for putting the quartz ampoules, prepared by the Czechoslovak Academy of Sciences, containing silver chlorides and copper and lead chlorides into the furnace.

7 NASA receives weak signals from Skylab *via* Bermuda station. *(It is hoped to reactivate the Skylab Workshop's thruster attitude control system (TACS) to cause it to go into a very slow tumble which would decrease the atmospheric drag and perhaps add several months to the orbital lifetime. Ed.).*

8 *Novosti* reports that other joint work carried out by the two cosmonaut crews aboard Salyut 6 include the "Extinctcia' experiment to "observe the change in stars' brightness when they set behind the Earth's night horizon. The object is to obtain data on micrometeoroid dust layer which exists at altitudes of 80 to 100 km." The cosmonauts "have also carried out a 'Chlorella' experiment with algae cultures in a nutrient medium; they have also conducted research into the cardio-vascular system using the airtight "Chibis' suit and the 'Polynom-2' equipment." Other medical experiments include the Czech 'Oxymeter' to study the "oxygen regime in human tissue under weightlessness." Orbit parameters of Soyuz 27/Salyut 6/Soyuz 28 are 338 x 357 km x 51.6 deg; period 91.8 min.

8 Lt-Gen Georgi Beregovoi, head of Gagarin Training Centre, names Soyuz 28 back-up crew as Czechoslovakian citizen Oldrzich Pelczak and Soviet citizen Nikolai Rukavishnikov. He also says "cosmonauts from Poland and the German Democratic Republic, who are completing their training, are to make flights this year. The second enrolment of cadets from Bulgaria, Hungary, Cuba, Mongolia and Romania will shortly begin their courses at the Gagarin Training Centre.

8 *Novosti* reports that automatic high-apogee Prognoz 6 station launched on 22 September 1977 has "sent the last recordings of over 4,000 spectra of the ultra-violet region including separate stars and stellar clusters. The Soviet-French instrument made it possible to obtain extensive data on the luminescence of a huge hydrogen cloud 100,000 km from Earth."

SATELLITE DIGEST-115

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information sources include the Space Department of the Royal Aircraft Establishment at Farnborough, NASA, Novosti and both the popular and specialist press. For a more detailed summary, see Satellite Digest – 111, January, 1978.

Continued from April issue, p. 158]

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin- ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 964 1977-110A	1977 Dec 4.50 12.76 days (R) 1977 Dec 17.26	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	171 169	362 303	72.88 72.88	89.85 89.24	Plesetsk A-2 USSR/USSR (1)
Cosmos 965 1977-111A	1977 Dec 8.46 6 years	Octagonal ellipsoid? 550?	1.8 long? 1.5 dia?	465	516	74.03	94.44	Plesetsk C-1 USSR/USSR
NOSS 2 1977-112A	1977 Dec 8.74 1800 years	Cylinder		1054	1169	63.43	107.50	WTR Atlas DoD/USAF (2)
Soyuz 26 1977-113A	1977 Dec 10.05 37.43 days 1978 Jan 16.48	Sphere + cone-cylinder + antennae 6570?	7.5 long 2.3 dia	195 251 337	235 321 354	51.64 51.62 51.59	88.74 90.20 91.39	Tyuratam-Baikonur A-2 USSR/USSR (3)
1977-114A	1977 Dec 11.54? indefinite	Cylinder 700 fuelled 350 empty?	1.7 long? 1.4 dia?	146 191	188 41002	29.9 28.2	87.68 733.2	ETR Atlas-Agena D DoD/USAF (4)
Cosmos 966 1977-115A	1977 Dec 12.41 11.87 days (R) 1977 Dec 24.28	Sphere + cylinder- cone? 5500?	5 long? 2.2 dia?	204	296	65.03	89.50	Tyuratam-Baikonur A-2 USSR/USSR
Cosmos 967 1977-116A	1977 Dec 13.66 1200 years	Cylinder?	4 long? 2 dia?	963	1005	65.84	104.77	Plesetsk C-1 USSR/USSR (5)
Meteor 2-03 1977-117A	1977 Dec 14.40 500 years	Cylinder + 2 vanes + 2 antennae 2750?	5 long? 1.5 dia?	856	894	81.22	102.48	Plesetsk A-1 USSR/USSR (6)
Sakura (CS1) 1977-118A	1977 Dec 15.03 indefinite	Cylinder 676 fuelled	3.51 long 2.18 dia	155 35568	35732 36157	28.70 0.06	629.28 1440.0	ETR Delta Japan/NASA (7)
Cosmos 968 1977-119A	1977 Dec 16.19 120 years	Cylinder + paddles 750?	2 long? 1 dia?	782	810	74.03	100.80	Plesetsk C-1 USSR/USSR (8)
Cosmos 969 1977-120A	1977 Dec 20.66 13.59 days (R) 1978 Jan 3.25	Sphere + cylinder cone 5500?	5 long? 2.2 dia?	180	317	62.81	89.45	Plesetsk A-2 USSR/USSR
Cosmos 970 1977-121A	1977 Dec 21.44 disintigrated	Cylinder?	4 long? 2 dia?	144 949	861 1141	65.16 65.85	94.67 106.04	Tyuratam-Baikonur F-1-m USSR/USSR (9)
Cosmos 971 1977-122A	1977 Dec 23.68 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	980	1010	82.93	105.04	Plesetsk C-1 USSR/USSR (10)
Cosmos 972 1977-123A	1977 Dec 27.33 200 years			716	1172	75.85	103.92	Plesetsk ~~C-1~~ F-1 USSR/USSR
Cosmos 973 1977-124A	1977 Dec 27.39 12.91 days (R) 1978 Jan 9.30	Sphere + cylinder- cone? 5500?	5 long? 2.2 dia?	203	325	71.25	89.81	Tyuratam-Baikonur A-2 USSR/USSR

Supplementary notes:

(1) Orbital data are at 1977 Dec 5.1 and 1977 Dec 9.2. A redundant manoeuvring engine was ejected during 1977 Dec 16; it is designated 1977-110D.

(2) NOSS stands for Navy Ocean Survey Satellite. Three other objects which may also be payloads are in similar orbits.

(3) Second attempt to place a crew aboard Salyut 6 (1977-97A), Soyuz 26 docked with the space laboratory's second docking unit on the instrument section at 1977 Dec 11.13. The crew comprised flight commander, Major Yuri Romanenko and civilian flight engineer Georgi Grechko. On 1977 Dec 19, Grechko performed an

EVA to inspect the forward docking unit prior to the Soyuz 27 launch (see next month's table), Soyuz 26 returned to Earth with the crew of Soyuz 27 thus leaving the aft docking unit clear for its intended purpose, docking of the Progress supply craft. At 1315 UT on 1977 Feb 2, Georgi Grechko passed the manned space flight cumulative record of 2017 hr. 16 min. set by the Skylab 4 crew. Orbital data are at 1977 Dec 10.1, 1977 Dec 10.7 and 1977 Dec 12.8.

(4) US military launch, data is unconfirmed. Orbits shown are at 1977 Dec 11, 1977 Dec 12, 1977 Dec 13 and are subject to correction at a later date.

(5) Target vehicle for satellite interception tests.

(6) Third of the second generation Soviet meteorological satellites scanning the Earth at infra-red and visible light wavelengths.

(7) Experimental Japanese communications satellite providing telephone and television links. The orbit is geostationary and the satellite is located at longitude 135 deg east. Orbital data are at 1977 Dec 16.0 and 1977 Dec 16.1.

(8) Cosmos 968 may be a military communications satellite.

(9) Intercepted Cosmos 967 target and then exploded. Orbital data are at 1977 Dec 21.5 and 1977 Dec 21.6.

(10) Cosmos 971 may be a navigation satellite.

BOOK REVIEWS

SETI: The Search for Extraterrestrial Intelligence
Edited by Philip Morrison, John Billingham and John Wolfe. NASA SP-413, US Government Printing Office, 1977, $5.00.

Since 1800, when Herschel discovered infrared radiation, we have vastly expanded our conception of the electromagnetic spectrum beyond the narrow band of visible light to include ultraviolet, X-rays, gamma rays, and radio. This has opened up new ways of perceiving the physical Universe revealing natural phenomena we had not expected. It also has suggested new ways of searching for extraterrestrial beings, and communicating with them.

The human species has entered a new communicative phase in this century. During the brief time since the Earth's radio age began, we have dramatically increased the power of our emissions in radio wavelengths, making ourselves more easily detectable at interstellar distances. We also have improved our ability to find aliens. The radio pioneers Marconi and Tesla believed they had detected intelligent signals of extraterrestrial origin, but were hooted into silence. Subsequently, radio engineers found that there were indeed radio sources beyond the atmosphere, though all appeared to be natural radiations from our Galaxy.

After World War II, radio astronomy emerged as a major science, equipped with larger antennae and better receivers. Astronomers mapped the radio sky, and found it very different. Our expanded technological capabilities, and the related improvement of our knowledge of the interstellar radio environment, led to a revival of the idea that other civilisations might use radio as a means of communication, even at interstellar distances. In 1959, Giuseppe Cocconi and Philip Morrison noted that there is a unique, objective standard of frequency which must be known to every observer in the Universe: the 21 centimetre (1,420 MHz) radio emission line of neutral hydrogen. Pointing out that the means of detecting such signals were at hand, Cocconi and Morrison argued that a discriminating search deserved a considerable effort.

Since this now legendary paper, an entire school of thought has grown up around the idea of detecting and communicating with aliens in radio wavelengths, and has given us a new acronym: CETI – Communication with Extraterrestrial Intelligence. Groups of scientists formed in the US, the USSR, and other countries to discuss this once exotic subject; many attended the historic Byurakan conference on CETI in 1971. At least nine searches have been conducted with existing radio telescopes, beginning with Frank Drake's Project Ozma in 1960. Scientists and radio engineers have written elaborate papers on search techniques and preferred wavelengths, centring on that portion of the microwave spectrum most easily observable through the Earth's atmosphere and least affected by the interstellar medium. A summer workshop held at the NASA Ames Research Center in 1971 proposed a huge array of radio telescopes for the search, and called it Project Cyclops. In 1975, a committee of the USSR Academy of Sciences proposed an extensive search programme, including the use of the giant RATAN-600 radio telescope.

After the Cyclops report, NASA formed a small working group on interstellar communication at Ames to do feasibility studies. In 1975 and 1976, six science workshops were held to discuss the questions raised by CETI. Separate but parallel workshops considered cultural evolution and the search for extrasolar planets. The results of these meetings are summarised in a new NASA Special Publication titled *SETI: The Search for Extraterrestrial Intelligence.*

The initial section of *SETI* presents consensus views on the search and its impact. The workshop participants concluded that it is both timely and feasible to begin a serious search, that a significant SETI programme with substantial potential secondary benefits can be undertaken with modest resources; that large systems of great capability can be built if needed; and that SETI is intrinsically an international endeavour in which the United States can take a lead. On the impact, the participants concluded that even a failed search would develop important technology and add greatly to our knowledge of the physical Universe. The global organisation of a search could have a cohesive and constructive influence on our view of the human condition. If we were to locate even one signal, we would know that a civilisation can maintain an advanced technological state and not destroy itself. We do not know what information content of a signal would be; it could provide us with important knowledge, and possibly link us with a chain of rich cultures. The participants make it clear that they do not propose sending signals; transmission should be considered only in response to a received signal or after a prolonged listening programme has failed to detect any signals. The searches proposed can be completed in about five years.

The workshop participants argue that the search programme must be kept open and public. International co-operation will be important, particularly for the solution of the radio frequency interference problem. Joint US-Soviet leadership of an international SETI programme might be logical continuation of cooperative endeavours in space.

The second section of *SETI* presents individual overview papers on cosmic evolution, cultural evolution, the detection of other planetary systems, the rationale for a preferred frequency band (the "water hole"), search strategies, and the science of SETI. Section III consists of 13 complementary documents, including technical papers on search methods.

The papers in *SETI* are generally readable for the layman, though some of those on search methods are fairly technical. One wishes that a major publication on this important subject were done more as a cohesive book than as a collection of papers. Nonetheless, the publication of *SETI* is another landmark in the slow climb of this idea to scientific respectability. Its appearance may coincide with consideration by the US Congress of a NASA budget request for a research programme using existing radio telescopes. Two complementary strategies are proposed: a high sensitivity, high resolution search of nearby promising stars and selected sky areas in the "water hole," conducted by NASA Ames, and a survey of most of the sky over a significant portion of the free space microwave window at lower sensitivities and resolutions, conducted by the Jet Propulsion Laboratory.

Extraterrestrial intelligence is no longer a matter of faith or wishful thinking, but an object for scientific research. In the process of studying this problem, we have been forced to think in interdisciplinary terms, integrating knowledge for many sciences. We have been able to see ourselves, our evolution, and our possible futures more clearly by speculating about extraterrestrial life. But we will need a new maturity for the contact that SETI may bring, so that aliens are perceived neither as a *deus ex machina* to solve our problems or as monsters from the id. Even if a radio search fails, we should not exclude the eventual detection of aliens by other means, perhaps from platforms in space, in other wavelengths, or in ways not imaginable to us now. And we should begin to think more seriously about how we should respond.

MICHAEL A. G. MICHAUD

Proceedings of the Sixteenth General Assembly of the I.A.U.
Eds. E. A. Miller and A. Jappel, D. Reidel Publishing Co., 1977 pp. 586, $50.00.

This substantial tome consists of the various reports given at the 16th General Assembly of the International Astronomical Union held in Grenoble in the summer of 1976. The IAU is the body which attempts, where possible, to coordinate the efforts of astronomers, worldwide, and these triennial General Assemblies are a chance to review progress.

The greater part of the book is taken up with short (two to three pages) reports of the many IAU Commissions. Among the subjects covered are positional astronomy, the Moon, variable stars, teaching of astronomy, high energy astrophysics and cosmology. However, these Commissions tend to be very specialised and although some will prove of interest to the more general astronomer the majority are only of value to those people working in the particular area. Each Commission reports on its membership, discusses current problems, suggests future conferences and often contains reviews of current work. The final report in this section is a major one from the Working Group for Planetary System Nomenclature. This is one of the more interesting sections as the Group proffer suggestions for the naming of features on the planets and the Moon. They also offer collections of names of classes of people (and things) to be used to name types of objects on particular planets, i.e. small craters on Mars will be named after cities and villages from almost every country on this planet; other features will be named after scientists, artists and composers and there are also some more traditional Latin names. The large number of names needed now is a sign of the activity of the various space agencies which are producing so many maps of these worlds from spacecraft surveys.

The *Astronomer's Handbook* gives the reader some information about the history of the IAU, its current membership and officials, followed by 140 pp. listing current members of the IAU with their addresses as of December 1975. This is probably one of the more useful reference sections of the book. The final section consists of the report of the Executive Committee and includes lists of recent meetings, publications, etc., besides the Union's accounts.

The cover says that this is a book for "all those involved and interested in space research;" basically it is a book to refer to in a major library. Like most official reports it makes for dry reading but, nonetheless, it is a useful reference book for the practising astronomer.

C. A. WHYTE

Highlights of Astronomy Volume 4
D. Reidel Publishing Co., Part 1, pp. 370, $34.00, Part II, 1977, pp. 405, $38.00.

The two parts of this book contain the invited discourses and the main proceedings of the 16th IAU General Assembly held in Grenoble in August 1976. The subjects covered, as the title suggests, are all ones of current interest in the research field, *viz:* X-ray astronomy, planetary exploration, galactic clusters, our own Galaxy, and various aspects of solar studies.

Of the two invited discourses published, the first one is by J-C Pecker from France on infra red galactic observations (in French). In this talk he firstly reviews current techniques in this field before moving on to interpret some of the recent results. Ice, graphite and various silicates are shown to be the main constituents of the large dust clouds in our own Galaxy. Other objects visible to the infra red telescope are the younger stellar members of our Galaxy and a range of molecules and atoms of great relevance to the origins of life.

The second discourse was that of the more widely known US scientist, Carl Sagan. He presents a very readable survey of satellite observations of the planets Mars and Venus, concentrating inevitably on the Viking results from the surface of the former. An impressive collection of recent photographs accompanies his article.

Then follows the seven discussion meetings on various aspects of astronomy. These are each collected papers on current research topics and will probably be only of interest to the workers in that field. They all contain a fairly balanced mixture of theory and experimental observations with contributions from many of the leading scientists in their fields. As such they provide a useful summary of the research interests in 1976 though their current value is diminished, as always, by the length of time taken to publish the proceedings. The price will also see to it that few copies will find themselves on the personal shelves of scientific workers, though it is well recommended as a reference work for libraries.

DR. M. J. COE

Topics in Interstellar Matter
Ed. H. van Woerden, (Astrophysics and Space Science Library, Vol. 70). D. Reidel Publishing Co., 1977, pp. 295, $30.00.

Although the mass of gas and dust dispersed between the stars of a galaxy generally represents only a fairly small fraction of its total mass, research into such galactic interstellar matter (ISM) has proved to be an extremely rich and exciting field of study, and currently is one of the most active fields of astrophysics. This book contains the twenty-four invited review papers presented on this subject at the

16th General Assembly of the IAU held in August, 1976. The subject material spans a broad range of topics, reflecting both the very broad variations in the physical properties found in ISM, and also the variety of experimental techniques used in its observation (which, in fact, span completely the electromagnetic spectrum from radio to gamma rays). The emphasis of all the reviews, however, is firmly on the detailed physical interpretation of observations, rather than on the experimental techniques themselves.

The picture of the interstellar medium which emerges from these studies in one of considerable complexity. At one end of the parameter scale we find hot, tenuous hydrogen plasma ($T \sim 10^6 K$, $n \sim 10^{-2}$ cm^{-3}) originating from both supernovae and the intense stellar winds of early-type stars, while at the other end we have the compact, dense ($n \sim 10^5$ cm^{-3}) molecular gas clouds, rich in dust and complex molecules, in which the temperature is within a few tens of degrees of absolute zero. These latter are particularly interesting as being the likely sites of present-day star formation, and the various aspects of their properties are extensively discussed (e.g. dust content and composition, molecule formation on dust grains and in the gas phase, relative element abundance etc.). One review also describes the recent use of the relatively intense millimeter wavelength emission from carbon monoxide in such cold clouds to map their large-scale distribution and kinematics within our Galaxy. Although molecular hydrogen is undoubtedly the dominant component of these dark clouds, it is itself not directly observable on a galactic scale. Thus the CO emission observations give important information on its distribution. These measurements are then complementary to those obtained on the more diffusely distributed atomic hydrogen which have been derived from 21 cm emissions.

The processes leading to star formation in dark clouds are not discussed in detail in this book, but the consequencies of their formation are. Such newly-formed hot stars radiate sufficient energy in the ultraviolet to ionize and heat the surrounding neutral gas, thus halting and reversing the gravitational infall which lead to their formation. Eventually the ionized regions break out of the dense cloud to become spectacular visible nebulae ($n \sim 10^2$ to 10^4 cm^{-3}, $T \sim 10^4$ K), the best known and most studied of which is that in Orion. The properties of such regions are also discussed in detail. Naturally, the most detailed observations of individual objects of these kinds may be made on those close at hand within our own Galaxy. However, in order to understand their relationship to over-all galactic structure (e.g. spiral arms, distance from the nucleus etc.) it is advantageous to study the ISM in other galaxies within our local group, and several reviews in this subject area conclude the book. In one of these the first definite detection of neutral hydrogen in an elliptic galaxy is reported.

In summary, this book contains a wealth of generally well presented information on recent studies of the ISM, representing the state-of-the-art as of about the beginning of 1977. The reviews were, of course, prepared for an audience of active research workers in the ISM field, but many of them are sufficiently self-contained that they may readily be comprehended by interested physicists ~~specialising~~ in ancillary fields. A short editorial foreword introducing each topic (as was done for one section) would have been advantageous in this regard. The book is well produced and not unreasonably priced by contemporary standards.

DR. S. W. H. COWLEY

Compilation, Critical Evaluation and Distribution of Stellar Data
Edited by C. Jaschek and G. A. Wilkins: D. Reidel Publishing Company,1977, pp. 320. $36.00.

This book describes the proceedings of I.A.U. Colloquim No. 35, held at Strasbourg, France on 19-21 August 1976. It is divided into five parts, and deals with aspects of astronomical data acquisition, standardisation, compilation, distribution and evaluation and also consideration of the future role for data centres.

Part I describes standards for the presentation of astronomical data. A paper appears,among other subjects, on the principles of a coded numbering system and its application, especially in relation to open clusters. A number of papers are also presented on various forms of stellar catalogues and include a bibliography for astronomical catalogues and organisation of stellar designations. The final paper describes use of S1 units in astronomy.

Acquisition and Processing Techniques are the subject matter of Part II, starting with a paper on the influence of acquisition techniques on the compilation of astronomical data. Later papers deal with such subjects as data processing and analysis for space-based astronomy, data storage requirements for radio astronomy purposes and Texas University cataloguing of astronomical and stellar data.

Part III consists of eight papers on critical evaluation of data. Particularly interesting are those by Anne B. Underhill and her associates which gives special attention to computer aspects of data evaluation, a paper by Argue and Miller on photometrical sequence and one by A.Batten on cataloguing for spectroscopic binaries.

Part IV describes distribution of astronomical data and contains a very interesting paper by Fiala and Seidelmann of the US Naval Observatory. Finally, in the Part V, six papers describe existing facilities and future role of centres for data. Among them is one by G. A. Wilkins of the Royal Greenwich Observatory, who contributes a short discussion paper describing the most likely future role for data centres for Astronomy. Concluding remarks are added by Dr. R. H. Garstang, of the Joint Institute for Laboratory Astrophysics, USA.

While the above book would be a very useful addition to any astronomical library and of value to those engaged in astronomical research, it is not likely to prove very useful to the amateur or layman.

A. J. JEFFRIES

OUR NEW FORMAT

We hope that Readers like the new-style issues of 'Spaceflight.' A range of four cover designs – with new typography and background colours – allows us to vary the picture content to give the very best presentation of the world's space photos.

A new Society logos, to appear on each cover, features our standard emblem – a winged rocket and three stars – on a black ground encircled by the words: BRITISH INTERPLANETARY SOCIETY.

Responsible for the new cover design and logos is the young typographical designer David M. Holmes. A Member of the Society, Mr. Holmes studied for four years at the London College of Printing, from which he obtained a degree in Typographical Design. During his four years in the Professional world, he has produced designs for such companies as Rymans, British Leyland, American Express, Thomas Cook, Thompson Holidays and Elizabeth Arden.

At present he is employed as Art Director for Expression Design, London, E.C.1., England.

CORRESPONDENCE

Utopia or Eutopia?

Sir, I've read with appreciative interest and general agreement Mr. John Allison's remarks (*Spaceflight,* February 1978, p. 76) about my *Extraterrestrial Communities* (*Spaceflight,* October 1977). However, I would like to comment on two points where I find myself at variance:

Point 1: He seems to think that human social organisation is incapable of much improvement, without genetic change. This negative attitude would have attracted John Ruskin's remark that: *"One of the most fatal sources of misery and crime lies in the generally accepted quiet assumption that because things have long been wrong, it is impossible that they should ever be right."* In any case, not all countries and blocs are equally badly organised. For instance, I understand from the Media that there has been no wildfire inflation or unemployment in Russia, despite the economically shattering and antisocial actions of OPEC... partly in consequence of which everybody in the Western World has gone money-grabbing mad.

Point 2: My remark that if the monetary system is wrong everything will be wrong is – very nearly – just what the eminent Economics expert G. D. H. Cole wrote in his book *Money – Its Present & Future* (c 1930). He actually said: *"Unless we get our monetary arrangements right it is highly probable that everything else will go wrong."* I myself have always thought that Cole probably knew what he was talking about. Certainly all past and present history proves that point. The only real hope is that a scientific monetary system will prevail. As indeed is in some degree seen in Russia today. (I'm sorry to bring in Russia: there is much wrong there; but it's not my fault where they are right).

Incidentally, it will I hope be seen in another sociological Essay I'm preparing that I'm not proposing a Utopia but a Eutopia. There is a world of difference.

H. E. ROSS,
Guildford, Surrey.

More Piggyback Aircraft

Sir, With reference to your article on Boeing 747/Shuttle piggyback forerunners (*Spaceflight*, January 1978, p. 13), the Luftwaffe had two ideas about how to use a similar concept during World War II.

The first of these was 'mistletoe,' a combination of a manned Messerschmitt 109 and unmanned Junkers 88. The latter, packed with explosives, was to act as an anti-shipping missile.

Artist's impression of DFS 228V-1 mounted on its Dornier 217 parent.

The second combination consisted of a rocket propelled D.F.S. 228 reconnaissance aircraft and Dornier 217. The operational concept of this combination was that the D.F.S. 228 would have been carried to the edge of the enemy defences and released. The pilot of the D.F.S. 228 would then fire his rocket to reach an altitude of 40,000 ft. After this he would use short bursts to reach the target at about this altitude. Mission completed, the pilot was to return by using up the rest of his fuel then gliding back to friendly territory. When the war ended powered flight trials of the D.F.S. 228 were about to commence.

A. R. FRANKLIN,
Croydon, Surrey

Humanity and Space

Sir, I was particularly interested by Dr. Jesco von Puttkamer's article "On Humanity's Role in Space" in your February issue of *Spaceflight*. In these days of concentration on the material questions of *how* to ensure survival of our planet and our race (enough food and energy, water, raw materials; optimum use of limited land and sea areas; systems for co-ordinated administration and planning throughout the world) it is a very rare event indeed to find someone posing the question *why* – what justification do we have, beyond egotism and vanity, for *trying to survive....* even trying to extend our frontiers beyond those of our little but remarkably hospitable planet.

Yet if we have no answer to that question, if our only concern is to guarantee that future generations (in the foreseen stable-state world of some 12 billion persons) will be able to be born, adequately fed and educated to survive in a more and more ant-like community, and finally to disappear virtually without trace after 70 to 80 years, then surely we might just as well pack up now!

This is why I salute Dr. von Puttkamer's paper, though at the same time I do not believe he goes far enough. Certainly he points to the educational and intellectual enrichment that must come (and to some degree already has come) from the new dimension of space – forcing us to view our world, our fellow beings and the problems before us all, in a new and surely far more rational perspective than hitherto. He talks of "intellectual, moral, spiritual, religious and other

factors: curiosity, love of adventure, search for truth, goodness, justice, wisdom and beauty, belief in higher goals, etc." He suggests that space flight may help us to "awareness of creation and destiny."

There is the real, fundamental and over-riding question: what is our destiny? Why should we strive to ensure the survival of our race? It is the oldest and by far the most important question for anyone who dares to believe he is more than a machine... a question which does not call for planning for survival, but for planning to survive for a purpose.

As I see it at present, the only real justification we have for trying to survive is that there *may* be a valid objective although we cannot see it (many of us of course believe this through our religions) and it would therefore be foolish to block the material way to its possible achievement by not "keeping the world running." (I believe, incidentally, that this sort of argument is no less true for a totally Marxist society than for any other). But it is a negative argument: we want to survive because there *might* be a destiny for us, and so we are devoting enormous efforts to forecasting population expansion, resulting food and energy demands, and so on. And Dr. von Puttkamer is reminding us that, if we cannot meet survival criteria on Earth for ever, then space could offer an "escape route." True, but the great question remains, "Escape *for what?*"

This letter is no attempt to answer that question... only to pose it as I see it, and as I am convinced it can be seen by many others. It is a plea for more research (international research), involving intellects from all disciplines and all societal systems) into the destiny of mankind and his *raison d'etre*.

I am of course aware that this is a "tall order," and that some will maintain it is asking the impossible (we used to talk of asking for the Moon!). To all those I would reply that, even if the research initially yielded little direct result, it might at least lead to an advance in moral and intellectual thought that seems so far to have failed to keep pace with scientific advance and material benefit.

Dr. von Puttkamer's paper reinforces my long-held conviction that those of us who have dreamed and speculated about space, and have already seen some of those dreams and speculations realised, could and should play a leading part in this special, and specially important, kind of research.

BRUCE M. ADKINS,
Gif-sur-Yvette, France.

Asteroid Path Changes

Sir, The O'Neill concept for moving mass from the surface of the Moon or for altering the trajectories of selected asteroids (the latter for the purpose of placing it in Earth orbit as a convenient source of mining metallic ores) has been discussed before various audiences [1]. However the operation of this 'mass driver' (so identified by O'Neill) and the consequences of such operation have yet to be examined in detail. This correspondence does not intend to impinge upon the question of the feasibility of the mass driver concept but is intended to raise some questions about the consequences of some of its proposed uses.

In a television broadcast concerning future space activity a scale model of the device was shown in operation at the Massachusetts Institute of Technology (MIT) [2]. It was suggested therein that 100 g was an acceptably useful acceleration. In the TV broadcast it was suggested that a 2 million ton (4×10^9 lb.) asteroid's path is to be altered.

Assume that an appropriate mass driver has been attached to the asteroid. Also assume that 'particles' of 100 lb. each are to be accelerated in sufficient number so as to cause a 1000 fps velocity change in the asteroidal velocity to ensure the aforesaid path alteration. Further assume that these particles are to be ejected at the rate of one per second (1/sec).

Now then, using a very fundamental formula:

$$F = ma = (W/g)(100\,g) = W(100) = T \qquad (1)$$

where all the symbols are obvious enough and T is the 'thrust' of the mass driver.

Thus it is seen that the thrust is equal to 100 times the weight of the driven particle. For the 100 lb. particle, the thrust is 10,000 lb.

But,

$$T = I_{sp}\,\dot{w} \qquad (2)$$

where, I_{sp} = specific impulse and $\dot{w}$ is weight ejected per second. w was selected as 100 lb/sec.

Thus, solving for I_{sp} in (2) we have a very low equivalent I_{sp} = 100 sec.

Using O'Neill's 2 million ton asteroid the portion of the celestial body to be expended (i.e., the equivalent propellant, 'W_p' for the purpose) is found with the use of the rocket equation in one of its familiar forms:

$$'W_p' = W_g[1 - e^{\frac{-\Delta V}{I_{sp}\,g}}] \qquad (3)$$

$$= (4 \times 10^9 \text{ lb})\,[1 - e^{\frac{-1000 \text{ fps}}{(100 \text{ sec})(32.2 \text{ ft/sec}^2}}] \qquad (3')$$

where, 1000 fps is the required velocity for the path change. 'W_p',therefore is 1.0664×10^9 lb; that is, 25% of the asteroid is required for the path change desired. For ease in further discussion let us assume that $W_p = 1 \times 10^9$ lb. (i.e., one billion lb.).

The particles are 100 lb. each hence there are;

$$10^9 \text{ lb}/10^2 \text{ lb/chunk} = 10^7 \text{ chunks} \qquad (4)$$

where the term chunk is found to be more descriptive, for the case, than is the word particle.

Also,

$$\frac{10^7 \text{ chunks}}{1 \text{ chunk/sec}} = 10^7 \text{ sec} = 2780 \text{ hr} \qquad (5)$$

If the chunks are 1000 lb. each, we have one million (10^6) of them produced in 278 hours.

Should the expulsion rate be raised to $\dot{w}$ = 100 lb/0.1 sec., then similarly (as above), we have,

2.2×10^7 chunks produced in 610 hr.

And 1000 lb/0.1 sec. yields,

2.2×10^6 chunks in 61 hr.

Also note that these two latter cases yield an I_{sp} = 10 sec., and

2.2×10^9 lb is expelled,

That is, over 50% of the asteroid is used to make the course alteration.

Consequently, we have a swarm of millions of 100 lb. or 1000 lb. pieces of an asteroid whose individual trajectories

vary greatly with the selected course for the to-be-captured asteroid. Only an appropriate computer program will be capable of determining with desired accuracy how many of these man-made meteorites will have trajectories that will intersect the Earth's path. It seems to me that their size may well preclude atmospheric-frictional destruction. Thus the mass driver may not be as benign a device as the untrained eye may perceive.

SAUNDERS B. KRAMER,
Gaithersburg, Maryland, USA.

REFERENCES

1. U.S. Congressional hearings on the future of space activity, Rayburn House Office Bldg. Rm. 2318, Wednesday, at 2 PM EST, January 25, 1978. The author was present at the hearings.
2. PBS (Public Broadcasting System) NOVA Program, UHF channel 26, Wednesday, at 8 PM EST, February 1, 1978.

Val Cleaver Memorial

Sir, I would like to add a few words to the memories of Val Cleaver expressed in the January issue of *Spaceflight*. Val was one of that rare breed of people who could combine a vision of the future with the common sense, scientific ability and political skills needed to turn a dream into reality. His friend Wernher von Braun was a similar example, and he must often have wondered how much more he might have achieved had postwar political conditions in the U.K. and Europe been different.

It is fitting that the BIS is planning a memorial to Val. He was one of the pioneers of astronautics in the U.K., being one of a small band of enthusiasts who joined the BIS in the years before World War II, and played a leading role in the prolific activities of the Society in the years between 1945 and 1955. Perhaps his most remarkable contribution was the series of articles on nuclear propulsion he wrote with L. R. Shepherd, which were well ahead of their time. No one made a greater contribution to the development of rocketry in the U.K., starting with his work on the Sprite and ending with the development of the RZ2 engine for Blue Streak and ELDO A. During all this he was tireless in his advocacy, both as a member of the Society and in his various government contacts, such as advisory committees, for U.K. and European launcher programmes and for advanced means of rocket propulsion, such as LH_2/LO_2 systems. air-breathing launch vehicles, electric propulsion and nuclear propulsion.

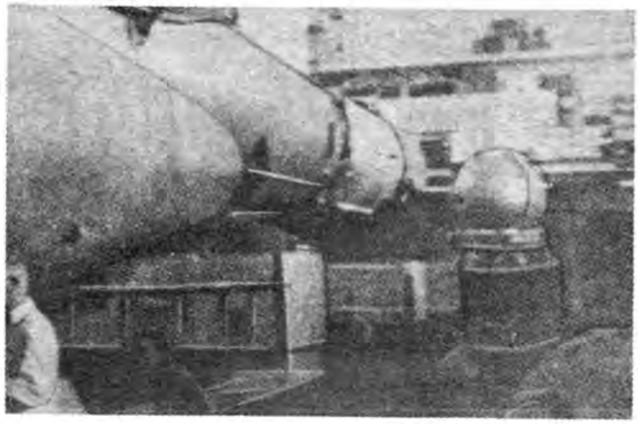
As Alan Bond has pointed out, it is difficult to assess Val's contributions to astronautics at this stage, but these must include the generous encouragement he has given to so many people, in particular young people just starting on their careers. I am sure I am just one of many people who can look back at such a stage in their lives, and feel a deep sense of gratitude for Val's efforts in trying to help careers, for his constant encouragement, and above all for his friendship. For this reason, I would like to suggest that it might be fitting if the memorial to Val Cleaver included some kind of permanent scholarship fund for the support of students embarking on a career in astronautics.

R. G. CRUDDACE
Washington, D.C., USA.

A recent estimate suggests that a permanent scholarship of the kind suggested by Ray Cruddace would need a capital sum of about £10,000 to produce an annual endowment of £400.

First Sight of Voskhod?

Sir, Whilst leafing through my files, I have discovered what may be the first full view of a Voskhod type spacecraft in assembly released by the Soviets'. The photograph, reproduced below, shows a 'Vostok' booster with what appears to be an upper stage of increased length, probably an A-2.



Does this photograph show a Vostok with an attached instrument package – or is it a Voskhod? (see 'First Sight of Voskhod?').

At the side of the rocket is at first glance what would seem to be a Vostok awaiting mating to the final stage. But a more detailed examination reveals a white protruberence atop the 'Vostok' sphere, where one would normally expect to find an antenna. The object compares favourably with the spare retro rocket flown on Voskhod 2 [1 and 2]. This retro rocket is also on a training photo released by the Soviets' showing Sergie Korolov and an unidentified cosmonaut [3]. Houtman [4] calls the cosmonaut 'Ivanov' (Pavel Belyayev's back up?). The $64,000 question, of course, is what mission, if any, did the Voskhod fly? Voskhod 2 would seem to be unlikely as no evidence of the airlock can be seen. Voskhod 1 did not, as far as can be ascertained from the open literature, fly with a retro package. Possibly it shows Cosmos 57 the Voskhod 2 precursor flight, or the Biosat Cosmos 110, or the ill-fated Voskhod 3 that cosmonaut Ivanov was training to use until Korolov's death in 1966 when the programme was abandoned to concentrate on Soyuz/Zond. A Voskhod type mission did fail on the launch pad; was this the spacecraft? Personally I do not rule out the possibility that the ship may be a reconnaissance satellite.

A final possibility is that it is an exhibition model in the Museum at Tyuratam/Leninsk. A similar building is depicted in Ref. 4, pp. 9/45 showing a Vostok and Zond 5's back up command module.

The only publication to carry the photograph in the writer's experience was a children's paper called *Countdown* which had a short existence in 1970/1. The photo has lain in my files for that length of time. The original is reproduced in colour.

NEVILLE KIDGER,
Morley, Leeds.

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1. Peter Sullivan, The Voskhod Spacecraft', *Spaceflight* November, 1974, p. 405.
2. Peter Smolders, *Soviets' in Space.*
3. *Steps Towards the Stars;* more details unknown.
4. *Spaceview*, April 1976, pp. 27/63.

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Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: Tel: 01-821 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor 12, Bessborough Gardens, London, SW1V 2JJ.

Main Meeting
Theme **OTS AND THE EUROPEAN TELECOMMUNICATIONS PROGRAMME**

A one day Symposium to be held in the Bartlett Lecture Theatre, University College London, Gower Street, London, WC1 on **1 June 1978**, 9.30 a.m. to 5.00 p.m.

The programme will include the following:

(1) Review of the OTS/ECS and Maritime Programmes by C. Wearmouth.

(2) OTS/ECS Sub Systems.

(3) OTS Test Programme by J. Lewis.

(4) The ECS System from a User Viewpoint by J. E. Golding.

(5) The Marecs Payload by M. Moody and G. Jones.

(6) Communication Satellite Systems for the 3rd World Based on the ECS Satellite by D. E. McLarin.

(7) In Orbit Performance of OTS Update by C. Wearmouth.

Offers of further papers are invited. Further information is available from the Executive Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ, England.

15th European Space Symposium
Theme **APPLICATIONS SATELLITES**

To be held in Breman, Germany, on **8-9 June 1978.** Co-sponsored jointly by the DGLR, AAAS, AIDAA and BIS.

Subject areas will emphasise the following aspects:

(1) Telecommunications Satellites.

(2) Meteorological/Remote Sensing Satellites, User and Ground Facilities.

Offers of papers are invited. Further information is available from the Executive Secretary.

33rd Annual General Meeting

The 33rd Annual General Meeting of the Society will be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **22 June 1978** at 6.30 p.m. A detailed Agenda appears in the April issue of *Spaceflight*.

Nominations are invited for election to the Council. Forms can be obtained from the Executive Secretary. These should be completed and returned not later than **11 May 1978.**

Should the number of nominators exceed the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all members.

29th I.A.F. Congress

The 29th Congress of the International Astronautical Federation will be held in Dubrovnik, Yugoslavia, from **1-8 October 1978.**

Further details will be announced later.

Southern California Meeting
Theme **SPACE: TODAY'S HOPE, TOMORROW'S REALITY**

To be held in Los Angeles, California, USA late **September** – early **October 1978.** A Symposium in three parts:

Part 1 – Survival: Holding the Fort

Part 2 – Reconstruction: Spring Cleaning

Part 3 – Expansion: New Horizons

Offers of papers are invited. Further information is available from Mr. A. A. J. Hooke, M/S 114-122, Jet Propulsion Laboratory, 4800, Oak Grove Drive, Pasadena, Calif. 91103, USA.

Film Show

To be held in the Botany Lecture Theatre, University College, London, Gower Street, London, WC1 on **11 October 1978,** 6.30-8.30 p.m.

The programme will be as follows:

(a) Reading the Moon's Secrets
(b) Mercury, Exploration of a Planet
(c) HEAO, the New Universe
(d) Images of Life

Admission tickets are not required. Members may introduce guests.

Film Show

To be held in the Botany Lecture Theatre, University College London, Gower Street, London, WC1 on **15 November 1978,** 6.30-8.30 p.m.

The programme will be as follows:

(a) Remote Possibilities
(b) The Weather Watchers
(c) If One Today, Two Tomorrow
(d) Mercury, Exploration of a Planet (Repeat)

Admission tickets are not required. Members may introduce guests.

PROJECT DAEDALUS – FINAL REPORT

Publication of the Daedalus Final Report has now been transferred from mid-April to mid-May as the material to appear has come out rather longer than anticipated.

The number of pages has, therefore, been increased from 160 to 192. Because of this, the price to non-members has had to be increased to £5.00 ($10.00). Members, however, may continue to order at the old price of £4.00 ($8.00) until 30th June, subject to stocks being available.

It is important to order without delay to take advantage of the present favourable rate. Copies from the second impression are likely to cost considerably more.

Orders and remittances to be sent to the Executive Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ.

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SPACEFLIGHT

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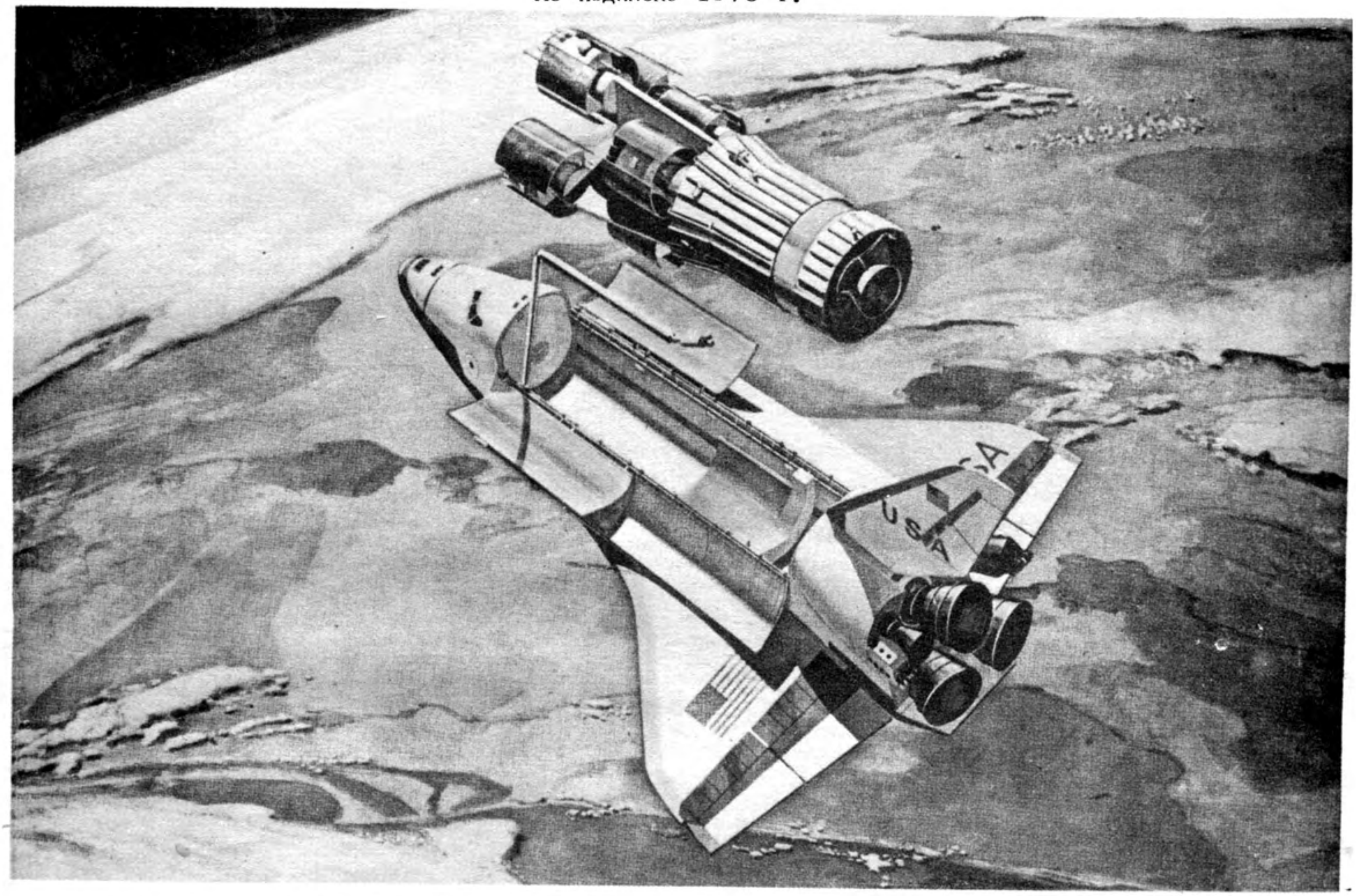

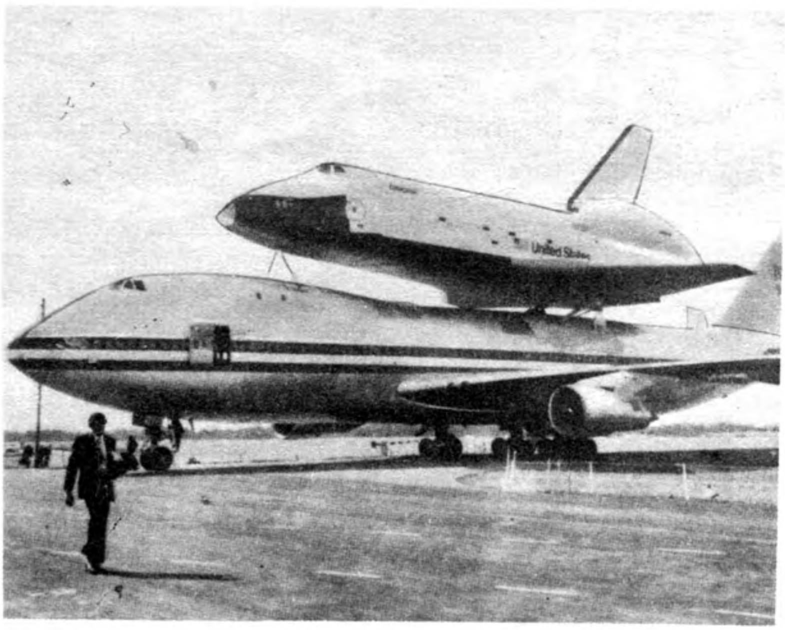

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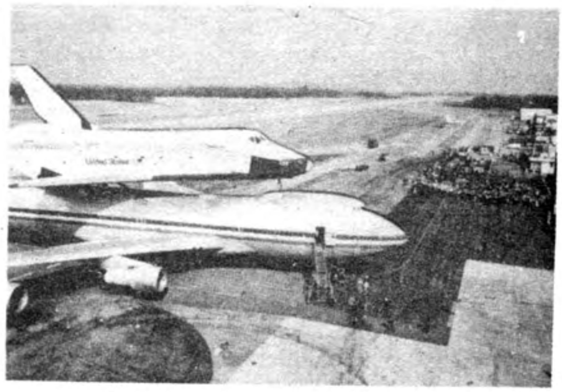

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Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

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COVER

SHUTTLE PROGRESS. *Top*, cluster of NAVSTAR Global Positioning System (GPS) satellites and attached propulsion stage are released from the Space Shuttle Orbiter in this artist's conception. These satellites will provide users with navigational fixes on Earth and in space that are accurate within tens of feet. *Below, left and right*, 'Enterprise' prototype arrives at Redstone Army Arsenal for dynamic testing at the Marshall Space Flight Center on 13 March 1978

Top, Rockwell International, bottom, exclusive British Interplanetary Society (photographer Mitchell R Sharpe

Cover design: David Holmes

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 20 NO. 6 JUNE 1978 *Published 25 May 1978*

MILESTONES

March

10 Soyuz 28 cosmonauts Col. Alexei Gubarev and Czech researcher Capt. Vladimir Remek soft-land 310 km (193 miles) west of Tselinograd in Kazakhstan at 16 hr. 45 min. (Moscow time). Flight controller Alexei Yeliseyev says aim of flight was to "check the capacity of an international crew to work successfully in space; thus Gubarev and Remek had not been overburdened with longer and more difficult tasks." The two men were up for seven days during which they carried out technological and bio-medical experiments including the 'Morava' experiment which studied the growth of high-purity crystals in weightlessness and also the possibilities of obtaining complex semi-conductor and optic materials. "Experiments with teams of cosmonauts from different countries under the Intercosmos programme are only just beginning," said Yeliseyev. "One of the possibilities still to be investigated is that of two crews making parallel experiments in space stations.

11 Anti-satellite laser code name 'Sipapu' (Indian for Sacred Fire) reported to be under test by the U.S. Army. Weapon depends on charged particles being neutralised through an exchange cell. USAF participation being conducted through Acceleration Division at Los Alomos Scientific Laboratory.

11 Cosmonauts Yuri Romanenko and Georgi Grechko aboard Salyut 6/ Soyuz 27 settle down to a weekend of medical experiments to allow doctors to assess their physical condition after 92 days in orbit. Results show that Romanenko's pulse rate is 66 and Grechko's 70; their blood pressures are 140/60 and 135/55 respectively. Cardiovascular systems remain "almost stable."

13 Orbiter 101 'Enterprise' arrives at Marshall Space Flight Center, Huntsville, Alabama, on Boeing 747 'mother' for vibration testing in vertical, take-off position simulating launch and powered flight loads. [It is now unlikely that 'Enterprise' will fly in space; vehicle is overweight and deficient in a number of respects. The flight models will be Orbiters 102, 099 (the vehicle currently being used for structure and dynamics load testing), 103 and 104. Ed.].

14 A 'sage brush' probe which would be blown by Martian winds to gather data is proposed by Jet Propulsion Laboratory, Pasadena, California. Inflated like a balloon it would deflate automatically or on command to collect data with a 44-66 lb. (20-30 kg) instrument payload.

14-15 Cosmonauts Yuri Romanenko and Georgi Grechko begin to prepare Salyut 6 for automatic period of operation following their long period of occupation. They transfer to the Soyuz 27 ferry materials of their experiments, documentation and films. A week before doctors had recommended that the two men should intensify their physical training since, from previous experience, it was recognised that adaptation from weightlessness to normal gravity conditions would be difficult after such a long flight.

15 *Novosti* reports that in-flight refuelling of Salyut 6 by the automatic cargo craft Progress 1 was accomplished from six tanks fitted with metal bellows which force-fed the propellants to the tanks under pressure from nitrogen stored in bottles at 200 atm. As refuelling began tank pressure was about 20 atm, says G. Lomanov. "To achieve the transfer, pressure in Salyut's tanks was reduced by pumping nitrogen back into the storage bottles using a powerful compressor on Salyut 6 run from chemical batteries re-charged from the solar cell array. It was a slow process owing to the drain on the batteries but it ensured that no gas bubbles were caused in the fuel supply."

[Continued overleaf

16 Cosmonauts Yuri Romanenko and Georgi Grechko end their record-breaking space flight. Soyuz 27 undocks from Salyut 6 at 1100 hours (Moscow time) and cosmonauts soft land 265 km west of Tselinograd, Kazakstan, at 14 hr. 19 min. (Moscow time). On-the-spot medical shows that both men stood up well to the marathon space flight which lasted 96 days 10 hours.

17 Professor Anatoly Egorov, head of medical group at Flight Control Centre, says mission confirmed that "it is quite possible for human beings to live and work in space for a year or longer."

17 NASA announces selection of four two-man crews to begin training for early orbital flights of the Space Shuttle. 1. John W. Young, 47, commander; Robert L. Crippen, 40, pilot. 2. Joe H. Engle, 45, commander; Richard H. Truly, 40, pilot. 3. Fred W. Haise, 45, commander; Jack R. Lousma, 42, pilot. 4. Vance D. Brand, 46, commander; Charles G. Fullerton, 41, pilot. Young and Crippen will be prime crew for the first orbital flight test (OFT-1) scheduled for launch from Cape Canaveral in June 1979 returning to Dryden Flight Research Center, Edwards, California. Engle and Truly are their back-up crew. Astronaut Donald K. Slayton has been appointed manager of the OFT Program at the NASA Johnson Space Center, Houston, Texas.

19 Soviet news agencies give details of early reactions of Romanenko and Grechko after returning to Earth. They had difficulty in picking up cups of tea and in walking at the Tyuratam cosmodrome where they rested after the mission. "They are both still up there in space, not only physically but also mentally," says Dr. R. Dyakonov. "When they wake in the morning they try to swim out of their beds. Their organs had become used to freedom from weight. Now every step is work – even turning a radio dial." Heart rate of one cosmonaut stated to have changed slightly and both experienced a withering of the calf muscles of their legs." None of these effects were expected to be long-lasting.

20 *Aviation Week & Space Technology* reports that Soviet delta-wing, manned, re-usable spacecraft has been 'drop-tested' from a Tupolev Tu-95 'Bear' over an isolated Soviet aeronautical flight test centre where the vehicle has been based for more than a year (see 'Soviet Space Shuttle', *Spaceflight*, June 1977, p. 211).

20 Japan's Space Activities Committee proposes 15 year space programme of 76 launchings costing $14,000 million. Includes missions by Japanese astronaut-scientists in U.S. Space Shuttle with special interest in materials processing and life sciences; sending unmanned probes to the Moon, Venus and Mars; various science and applications spacecraft and new boosters: up-rated N-launcher based on McDonnell-Douglas Thor, 1980, new Japanese H-launcher (lox/hydrogen) to place 5,000 kg into low Earth orbit or 800 kg into geostationary orbit, 1984. First scientist-astronaut flight in 1983; gamma-ray lunar orbiter about 1984; Mars and Venus launches late 1980's/early 1990's, latter to eject balloons into atmosphere.

21 At meeting of ESA joint communications board in Paris, West Germany agrees to become full partner in European Communications Satellite (ECS) programme; will contribute 30.68 per cent of development cost. Total cost of project at 1977 prices estimated $145 million.

25 Range safety officer at Cape Canaveral blows up Titan IIIC rocket carrying pair of USAF DCCS II communications satellites meant to be placed in geostationary orbit. Failure occurred in second stage; 'destruct' was commanded some eight minutes after launch.

30 Soviet Union launches Cosmos 997-998 by one carrier rocket from Tyuratam into orbit of 200 x 230 km x 51.6 deg. *Novosti* communiqué states: "The Sputniks' carry scientific apparatus and also have radio systems for precise measurements of the orbit elements and radio telemetric systems for transmitting to Earth data on the functioning of the instruments and scientific apparatus. The scientific investigations envisaged by the programme have been carried out." (Mission resembles that of Cosmos 881/882 carried out in December 1976 when both 'sputniks' were returned in 0.93 day. Experiments probably related to Soviet manned space programme. Ed.).

31 Soviets launch 1,000th satellite of Cosmos series into orbit of 978 x 1,024 km x 83°; period 104.9 min. Brings first official admission of Soviet "global, all-weather and highly accurate system for navigation of ships" depending on Doppler shift of fixed frequency signals processed by shipboard computer. Cosmos 1,000, described as "space radio beacon," carries a radio system for precise measurement of orbit elements and radio telemetry system for transmitting instrument readings to Earth.

31 NASA launches sixth and last Intelsat 4A satellite by Atlas-Centaur from Cape Canaveral. Will be placed in geo-stationary orbit above Indian Ocean.

April

4 Soviets' launch Cosmos 1001 into orbit inclined at 51.6 deg to equator in test exercise apparently related to manned space programme. According to NORAD, the vehicle initially (rev 2) was in a near-circular orbit of about 213 km. A thrust impulse modified this to 205 x 249 km and by rev 28 the orbit parameters had changed again to 207 x 276 km. Test may be related to Cosmos 929.

5 At Geneva meeting of 47-member United Nations' legal sub-committee on the Peaceful Use of Outer Space, Canada calls for work to begin on code of safety, notification and assistance measures to reduce "special hazards" posed by nuclear-powered satellites such as Cosmos 954 which disintegrated over north-western Canada on 24 January. United States and 12 other nations support the move, which ensures discussion by full Committee which meets in New York in June.

6 Contact with Voyager 2 is lost due to failure of on-board receiver. System scheduled to switch to stand-by receiver on 13 April although this too has been giving trouble.

6-7 Council of European Space Agency votes initial funding of $23.7 million (21.1 million Accounting Units) for manufacture of five production Ariane launchers. West Germany agrees to join nine other ESA member-countries in funding Phase B definition study of proposed H-satellite for experiments in direct-broadcasting.

SWITCHBOARD IN THE SKY

By S. W. Fordyce,* L. Jaffe* and E. C. Hamilton†

As part of our long-standing policy to bring important new ideas in Space Technology to a wider, international public we are pleased to publish a major feature on the vast potential market for domestic satellite services which is now being opened up in the field of communications. Such major developments in the coming decades will be the final vindication of the ideas first placed before the world by Arthur C. Clarke, a former distinguished chairman of the British Interplanetary Society, in 1945. The original Memorandum, entitled 'The Space Station: Its Radio Applications,' is now in the archives of the Smithsonian Institution in Washington (see *Spaceflight*, March 1968, pp. 85-86, Ed.).

A concept is presented for a large satellite platform in geostationary orbit that can support multiple communications satellite systems while providing subsystems support and on-board switching facilities. The National Aeronautics and Space Administration (NASA) could operate the platform and provide "room and board" to communications common carriers at lower costs per circuit year than can be achieved on individual, independent communications satellites. Cost savings would be derived from subsystem sharing among multiple payloads and revisitations *via* the Space Transportation System (STS) for the repair or replacement of units that have failed or become obsolete.

Although this presentation is addressed to domestic satellite (domsat) communications systems, the concept can easily be generalised to a network of worldwide platforms [1].

The Problem

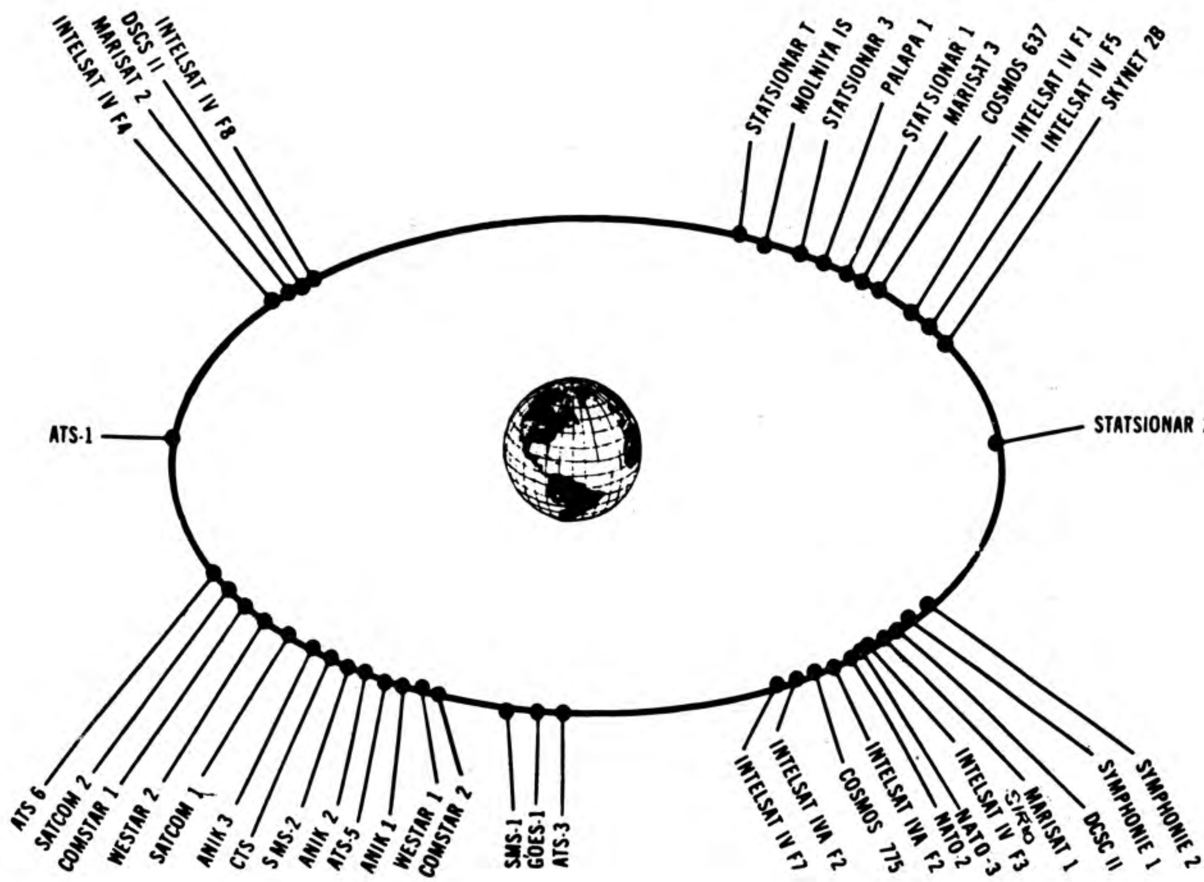
MORE THAN 60 SATELLITES have been placed into geostationary orbit since NASA's Synchronous Communications Satellite II (Syncom-II). The current population of operational geostationary satellites is shown in fig. 1. Most of these are communications satellites that tend to be bunched at longitudes providing views of land areas with heavy communications traffic.

This "prime real estate" is highlighted in fig. 2, which shows nine commercial communications satellites and one experimental communications satellite in the geostationary arc over North America. These satellites all operate at the C-band allocation for fixed communications (point-to-point) by satellite; i.e., 6 GHz up, 4 GHz down. They are spaced approximately 4 degrees apart in the orbit to avoid mutual radio frequency interference, primarily through reliance on narrow beam Earth station (E/S) antennas.

The original requirement for the minimum E/S antenna diameter in the United States was 9-m. A 9-m antenna has a beamwidth of approximately 0.6 degrees at 4 GHz so that the transmissions from neighbouring satellites were in the antenna sidelobes and sufficiently attenuated relative to those in the main beam. Recently, however, the Federal

* *NASA Office of Application, Washington, D.C., USA.*
† *NASA Marshall Space Flight Center, Huntsville, Alabama, USA.*

Fig. 1. Operational geostationary satellites.



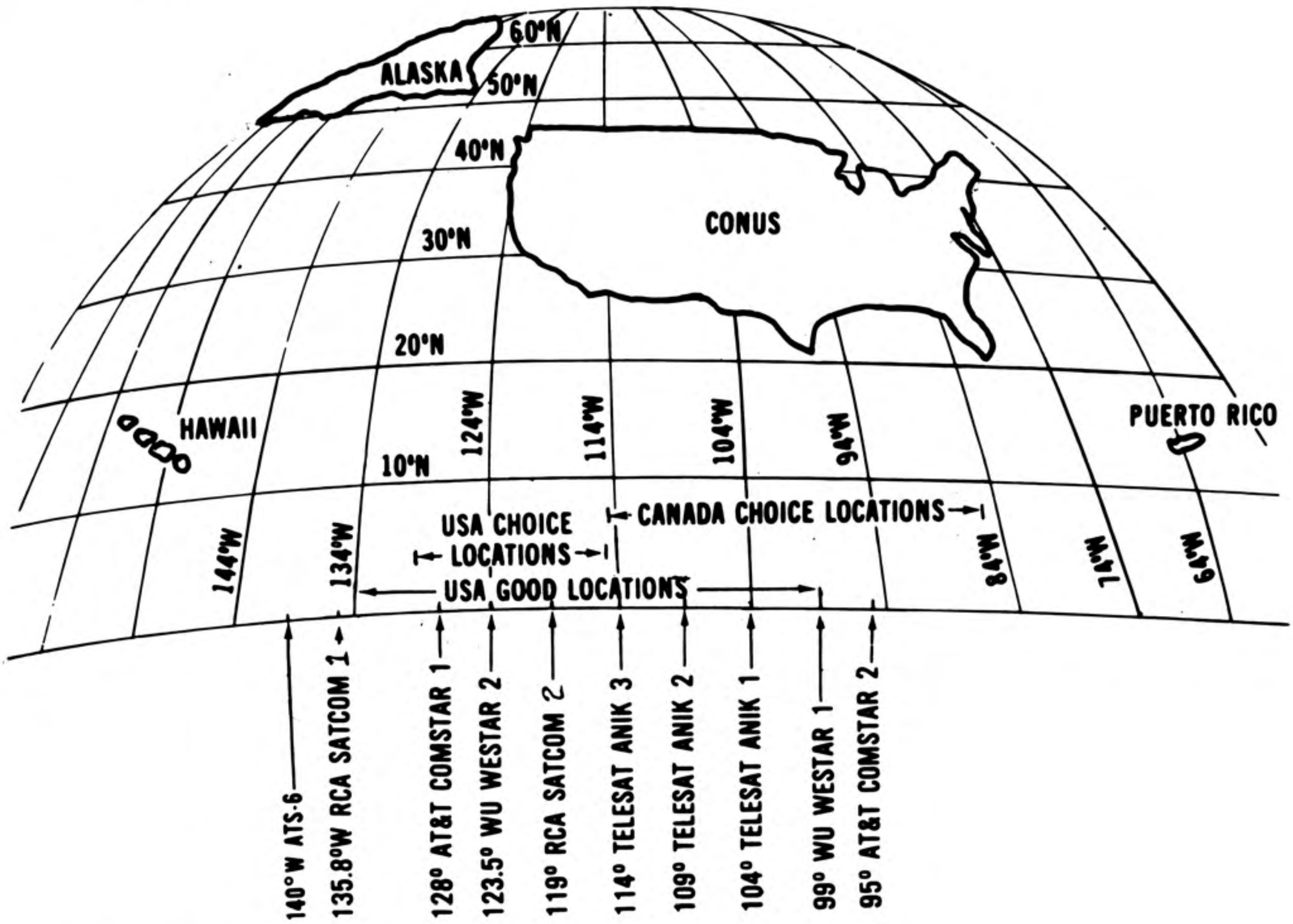


Fig. 2. Prime real estate-Geostationary Communications Satellites over North America (C-band).

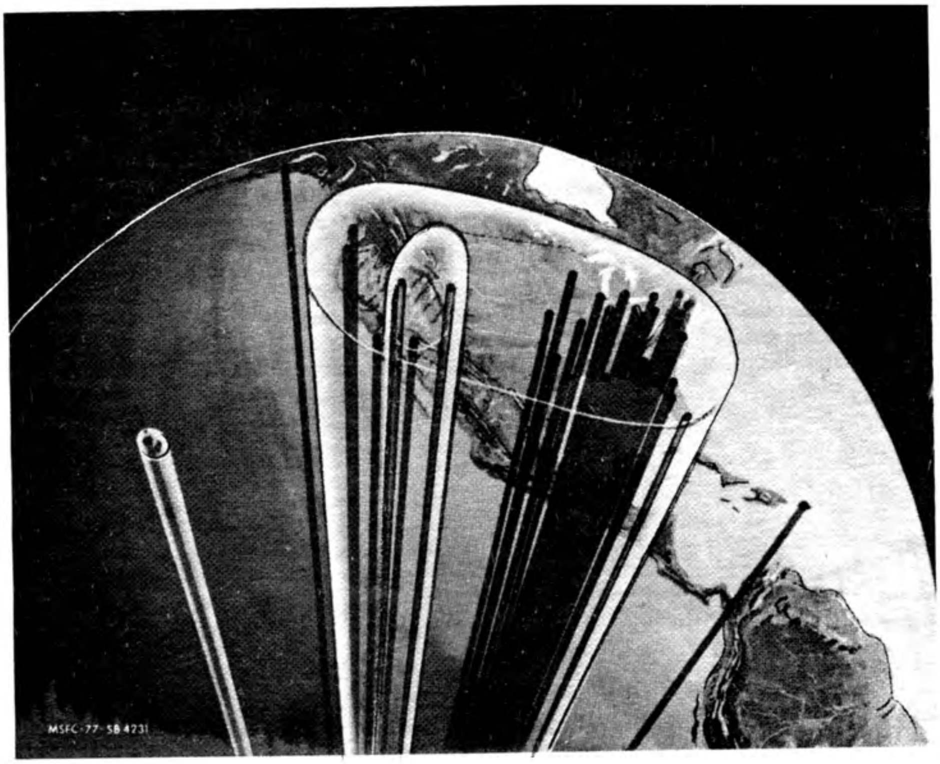


Fig. 3. Spot-beam C-band pattern covering the United States.

All illustrations National Aeronautics and Space Administration

Communications Commission (FCC) has indicated they will permit antenna diameters as small as 4.5 m for receive-only E/S applications. Since 4.5-m antennas have twice the beamwidths of 9-m dishes, transmissions from neighbouring satellites will be less attenuated.

The nine commercial satellites practically exhaust the geostationary orbit capability at C-band over North America. Four of these satellites now use cross-polarisation to increase their capacity from 12 to 24 transponders (36 MHz wide). (Each transponder can carry one television channel or approximately 1000 one-way voice circuits.) Currently, the total capacity over North America is 156 transponders. The next series planned includes three Satellite Business Systems (SBS) launches, which will add capacity at Ku-band that can be overlayed in the C-band galaxy without fear of interference.

Another step could be the addition of a third frequency band at 30/20 GHz. This band will be tested on Japan's Communications Satellite (CS), which was launched this year. While a K-band capability could add substantially to the domsat capacity, water vapour attenuation in the Earth's atmosphere may be a problem. The development of multiple (spot) beam satellite antennas, and the re-use of the allocated frequency bands in each spot beam may be an even greater contribution than the use of additional frequency bands.

Figure 3 illustrates a 33 spot-beam C-band pattern covering the United States. A 30-m diameter reflector with suitable off-set feeds would produce "footprints" on the Earth's surface approximately 100 km in diameter. Adjacent footprints could use cross-polarisation to decrease mutual interference. A single geostationary satellite with such an antenna could more than triple the present capacity of the entire C-band domsat orbital arc. Adding similar antennas at Ku-band and K-band could further increase capacity.

Additional communications capacity and throughput may also be obtained with digital processing payloads that would decouple some of the uplinks and downlinks for improved switching and routing control flexibility and channel matching efficiency. Such a processing satellite could automatically reconfigure itself to handle the most urgent user traffic according to priority, message length, and destination. Advanced multiple-access techniques involving sophisticated modulation schemes, spectrum spreading and demand assignment promise less crosstalk interference and a greater use of available capacity. A large accessible platform could easily support ample and reliable on-board computation for accomplishing these tasks.

The Market

The bulk of the domsat market is in the lease of private line communications for business and government organisations. This market is growing rapidly, and can support many more domsat channels in 1985. The use of new frequency bands can permit some growth, but more advanced technology is also needed.

The market potential is mainly in private business voice or data communications. This involves the lease of dedicated circuits or private lines from a carrier. The equipment included in this essentially retail market is either user owned or leased and operated for dedicated networks. The most significant users are in financial industries, transportation industries, public utilities, and government organisations.

The annual growth rate of this market sector in North America is projected to be 10 percent to 12 percent for the 1975 to 1985 time period. This rate could be increased if the current argument on the right of the lessee to sublet communications circuits to organisations other than his own is upheld in the courts.

The Department of Commerce has estimated $ 1.8 billion as the current revenues of the private line market in the United States. In 1975, the market share was divided as shown in Table 1.

TABLE 1. CY 1975 Private Line Revenues

Organisation	Revenues (Billions of $)	Market Share (%)
AT&T	1.455	81
Other Telcos	0.137	7
Western Union (Terrestrial)	0.155	9
Specialised Common Carriers	0.036	2
Domsats	0.016	1
Totals	1.799	100

The Department of Commerce projections of fig. 4 show the private line market increasing at an annual rate of 11.8 percent (1977 dollars) to a total of $ 5.5 billion in 1985. Although revenues increase for all of these organisations, the 50 percent rate of increase for the domsats is the highest rate by far. The domsats share increases from less than 1 percent to 16.4 percent (or $ 0.9 billion) of the total in 1985.

Assuming that the domsat space segment leases produce revenues of $ 1 million per fully-used transponder per year,

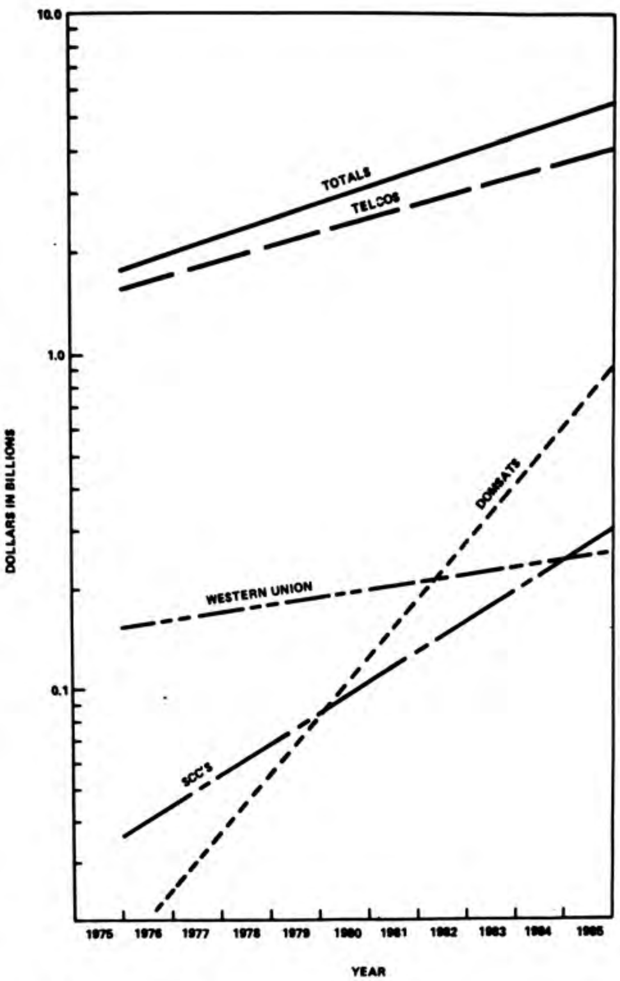


Fig. 4. Private line market estimates (Dept. of Commerce).

the 1975 domsat revenues required 16 transponders, but the 1985 revenues will require 900 transponders. Assuming a 50 percent satellite load factor, the number of transponders required in orbit over the United States was 32 in 1975 and will be 1800 in 1985. U.S. domsats now provide 120 transponders; the three Canadian Aniks provide an additional 36. Hence, at $ 1 million per transponder per year and 50 percent loading, this North American C-band galaxy could support a $ 78 million per year market. Even if this capacity were doubled by a Ku-band galaxy of domsats over North America, the market support could handle only 17 percent of the estimated domsat market in 1985. Clearly, steps are needed to increase satellite capacity.

The payloads under consideration for inclusion on the space platform are not limited to domestic satellite communications applications, but include the following communications services.

- Fixed Communications Satellite Service (Point-to-Point)
    1. C-band, as supplied by the current six U.S. domsats.
    2. Ku-band, as planned by the SBS and Tracking and Data Relay Satellite (TDRS) domsats.
    3. K-band, experimental communications similar to Japan's CS Program.
    4. S-band, thin-route public service communications.
- Mobile Satellite Communications Service
    1. L-band communications with ships, as in the Marisat, and planned for the Marots Program.
    2. VHF and L-band communications with aircraft, as was planned for Aerosat.
- Broadcasting Satellite Service
    1. S-band broadcasting of public service television, as conducted on NASA's Applications Technology Satellite-6 (ATS-6).
    2. Ku-band video broadcasting, as conducted on the Communications Technology Satellite (CTS) and planned in Japan's Broadcast Satellite (BS) Program.
- Space Research, Meteorology, and Earth Observation Satellites.
    1. Space-to-space communications, as planned on the TDRS.
    2. Meteorology, as in the Synchronous Meteorological Satellite/Geostationary Operational Environment Satellite (SMS/GOES) Program.
    3. Earth observation from geostationary orbit, data collection, etc.
- Navigation, Ship Surveillance, Other Data Collection
- Other Public Service
    1. Search and rescue.
    2. UHF communications with land mobile vehicles planned as an experimental NASA program.
    3. Thin route communications to small terminals as proposed for experimental rural communications satellites.

The Concept

Nearly all domestic satellite services could be accomodated on one geostationary platform. The goal of the communications equipment on this Geostationary Communications Platform (GCP) is to supply all of the services expected from the current and planned U.S. domestic communications satellites (Westar, Satcom, and Comstar), mobile communications satellites (Marisat and Aerosat), broadcasting satellites (ATS-6 and CTS), space research, meteorological and Earth observation satellites TDRS, SMS, and GOES), and provide for experimental communications.

The spacecraft useful weight on-orbit will be about ten times larger than the largest commercial communications satellite ordered to date. The dry weight of the GCP on geostationary orbit is expected to be about 8200 kg (18,000 lb). The entire payload of the STS or space shuttle will be required to bring the component parts to low-altitude Earth orbit in three launches, where they will be assembled and tested prior to being transported to the geostationary orbit.

The GCP subsystem will benefit from economies of scale, so all feasible geostationary payloads would be incorporated. Physical space and utility (subsystem) support would be leased by NASA to the transponder owners, who would provide their equipment to NASA to be integrated onto the platform. These owners would have the same perogatives of access, command and control that they have on conventional satellites, but would be freed from concern about the development and operation of the subsystems.

The current practise of launching independent satellites for each communications function is expensive as each satellite is required to furnish its own subsystems. The antennas, supporting structure, primary power supply, attitude control, stationkeeping, thermal conditioning, command and telemetry, and on-board computer and programming functions could be supplied much less expensively and much more reliably from a central platform accommodating multiple communications functions.

Initially, individual payloads would have to be developed to NASA interface specifications. Potential intermodulation and antenna blocking problems would have to be solved. Subsequent improved versions of payloads and support equipment could replace the originals during periodic maintenance visits.

Several NASA Centers are proceeding with studies and developments concerning fabricating and assembling large structures in space [2]. Lightweight structural beams have been successfully tested and assembled in a simulated zero-g environment. Huge antennas will be possible.

Another important advantage of a central platform stems from the ability to switch among communications transponders. At present, a specialised communications satellite such as the Marisat includes links to ship terminals and dedicated E/S. A telephone call from a ship to an inland terminal is routed through Marisat to a dedicated E/S on the coast, and hence on terrestrial circuits. The satellite-to-E/S links could be eliminated for such specialised functions on a GCP by means of on-board switching to fixed communications (point-to-point) services that reach an E/S close to the ultimate destination. The same principle can be applied to other communications satellite functions.

Further advantages stem from the increased reliability that would be incorporated into a central platform. For example, the primary failure mode in communications satellites has been connected with the attitude control subsystem. The GCP could afford back-up or redundant systems.

The Cost

Rough estimates, indicate that the space segment costs related to domsats. In addition would be less than those for the original domsats. In addition to the cost cuts, the communications service should be as good or better, and the growth capability would increase substantially. Growth would result from the lower costs of

providing long distance private line service by satellite rather than by terrestrial circuits. Even lower costs for domsat circuits could accelerate this growth.

The cost of the present North American domsats are shown in Table 2 and the satellite cost trend per two-way-voice-channel year is shown in fig. 5.

Can the C-band fixed-satellite segment of the switchboard-in-the-sky be developed and placed into geostationary orbit for a comparable cost? The GCP concept has some added attractions, such as greater growth potential, better use of the available geostationary arc, and the capability of reaching smaller E/S's. Nevertheless, it should be shown that the GCP can provide the basic domsat communications services cheaper than by the current galaxy of domsats. Preliminary estimates of the cost of the platform devoted to communications support are on the order of $ 215 million. This could mean savings over the alternate prospect of replacing all nine North American domsats with separate satellites, but relevant cost tradeoffs should be carefully addressed.

The Prospects

The real promise of satellites is in their ability to be used globally, to be time shared by many, and to respond to rapidly changing demands. Sooner or later we will want to communicate with extremely small and inexpensive ground terminals. This can be accomplished effectively only with large space structures; e.g., big antennas, and on-board processing; switching and demodulation/remodulation.

NASA can design, build, operate, and maintain space stations such as the large Geostationary Communications Platform. It would seem that the logic of having NASA operate such a station is but a small extension of NASA's space shuttle responsibilities. Since space stations will have multiple users, the facilities should be equitably shared and fairly managed to ensure that the best interests of all are served. In this area the most challenging problems are less technological than organisational and institutional.

Communications Payload

The capacity of a communication satellite depends primarily on the product of its radiated power and bandwidth, and both parameters depend greatly upon antenna technology. How efficiently the available capacity is used depends on the signal structure and the associated processing of the signal by the communication system. Each factor can have a significant impact on system efficiency and correspondingly on cost effectiveness.

The antenna plays the role of the RF interface in the Earth/space link. It provides directivity (gain), isolation and coverage. Primary concerns are mass, size, and cost; and these, in turn, impact on the viability of the systems that are designed. Combining many communication missions on a single large platform to replace separate spacecraft gains economies of scale by providing common support functions to multiple payloads and a common powerful processor to service all missions, as well as permitting a very large and complex antenna and feed system to be placed in geostationary orbit. The antennas under consideration include distributed phased arrays, lenses, and parabolic reflectors with offset feed systems.

Projections of the antenna technology for 1990 include arrays using strip-line and solid-state technologies; lenses using lightweight dielectric materials which in turn also increase bandwidth, and reflectors with improved surface tolerances and increased feed efficiencies.

Although most spacecraft have several antennas, they generally support a single mission by handling different frequencies, covering different regions, or adding telemetry.

TABLE 2. North American Domsat Space Segment Cost

Carrier	Satellite	Costs (Millions of $) Satellite + L/V's = Total
Telsat	ANIK 1, 2, 3	30 + 33 = 63
Western Union	Westar 1, 2	22 + 22 = 44
RCA	Satcom 1, 2	49 + 29 = 78
AT&T	Comstar 1, 2	32 + 42 = 74
Total:		259

On the GCP, however, each antenna system might perform roles in several missions. Conversely, each mission might use a number of different antenna systems. For example, a lens antenna system could be configured with the multiple spot beams shown in fig. 3, and with the beams optimised in such a way as to make it feasible to implement frequency re-use and still minimise co-channel interference. Several different missions might use this one antenna as an uplink, but each mission would have its own separate downlink transmitter and antenna.

The platform would have a separate electronics module for each mission. Except for their design and physical size, these packages would not differ greatly from those serving single mission satellites.

A typical module for a communications mission would consist of transponders operating at the appropriate frequencies and bandwidths. It would connect to the antenna systems servicing the mission. The transponders would be composed of the usual elements: low-noise receivers, fre-

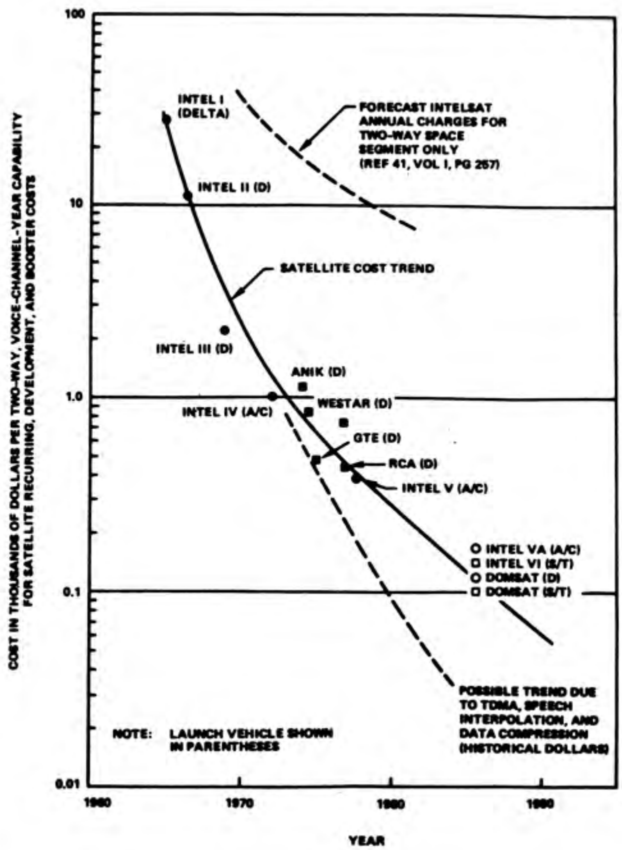


Fig. 5. Satellite cost trend per two-way, voice-channel-year.

quency conversion equipment, intermediate and high-output amplifiers, filters, and multiplexers.

In currently existing communications systems all processing and switching is done in the ground-station. However, the technology is here to implement very fast and complex processors onboard satellites. The co-location of multiple communications missions on a single platform makes it economically feasible to have complex processors on board to both perform signal processing and interconnect or cross-strap communication links from different missions.

Onboard processing represents a set of generic techniques, involving real or near-real time processing or switching, and can be used on the satellite to improve the performance level of the total communications system [4, 5].

In a multimission satellite communications system, co-channel interference will become a factor in signal degradation because of the measure being taken to augment the satellite communications capacity with frequency re-use by multiple spot beams. Isolation of uplink and downlink by an onboard processor can be used to reduce the effects of noise and interference prior to switching signals.

In a large multiuser distributed system with multiple beams on the satellite, the ability to interconnect all the users in an effective fashion becomes a difficult task. With a static satellite switch, the interconnectivity is fixed, but with an onboard processor, rapidly changing connectivity can be achieved. This can be accomplished by changing the transmission paths, dynamically re-routing bits or actually changing the access format. In addition, more sophisticated network control can be developed to efficiently use demand-access systems or incorporate certain forms of random access.

Onboard processing can increase the satellite amortization rate by providing the flexibility to effectively use the basic capacity associated with a satellite design; i.e., to reconfigure the satellite according to user need to achieve a high satellite fill factor. In addition, in some cases reduced Earth segment costs can result because simpler and less costly modulation or access schemes can be used without significant performance penalties.

At the present time the state of the art in processors is represented by a 16 x 16 RF satellite switch that has been developed for possible use in the Intelsat system [13]. However, with the rapid developments in large scale intergration technology, microprocessors, surface acoustic waves, and charge coupled devices, an increased technology base is available to implement processors that will support the needs of the GCP.

Space Platform Concept

Platform Structure

Several of the NASA centers have studied and made conceptual designs of large structures in orbit for various applications such as collection and transmission of solar power to Earth, orbiting antenna farms and manned space stations. Several approaches to the type of structure and its assembly procedures have been considered by NASA Marshall Space Flight Center, Alabama. The selected structural configuration of the GCP is depicted in fig. 6. The built up truss sections provide the necessary rigidity and mounting surface to accommodate the commercial services' antennas listed in Tables 3 through 6 and discussed subsequently. The ratio of length to width of the platform evolved from considerations of the antenna locations, stabilisation system, solar arrays, and facility in stationkeeping manoeuvres using hydrazine reaction control systems.

The beams are fabricated out of anodised aluminium tape 0.038 cm (.015 in.) thick and 17 cm (6.7 in.) wide. Beam forming is done directly from the roll by forcing the tape through a die resulting in a continuous channelled section similar to the forming of seamless gutter for homes as

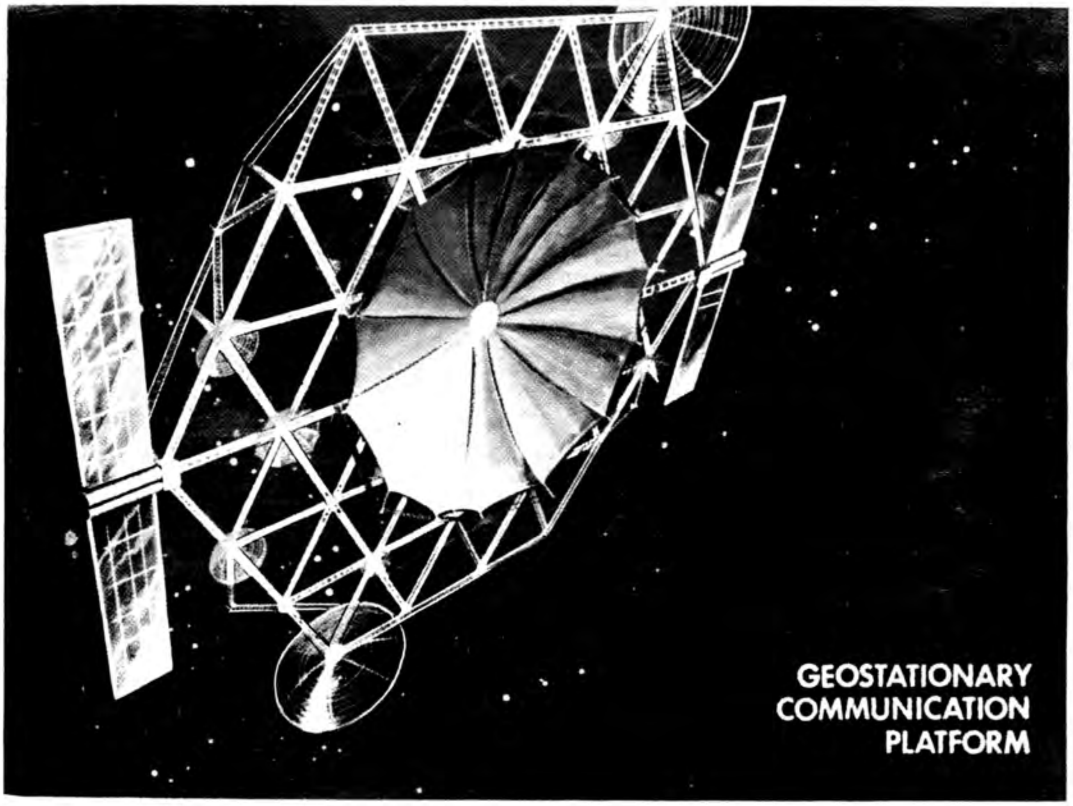


Fig. 6. Geostationary communication platform.

TABLE 3. Fixed Communications (Point-to-Point) Satellite Characteristics

Carrier Freq (GHz)	Band-width (MHz)	Peak Trans. Power (W)	Antennae	Comments
6/4	250	Two 40 W	Two 0.7 m x 2 m	CONUS coverage
6/4	250	Forty 0.25 W	One 30 m dia.	Forty spot beams
14/12	500	Forty 4 W	One 12 m dia.	Forty spot beams
14/12	500	Four 4 W	Four 4,5 m dia.	Four spot beams
30/20	1000	One 2 kW	Small Horn	CONUS coverage
30/20	2500	Ten 4 W	One 2.0 m dia.	Ten spot beams
2.6/2.5	35	Two 100 W	one 1 m x 3 m*	CONUS coverage

Total peak transmitter power = 1.4 kW
Total prime peak power requirements = 3.3 kW

* Multiplexed with S-band and C-band

TABLE 4. Mobile Satellite Communications Service Satellite Characteristics

Carrier Freq. (MHz)	Band width (MHz)	Peak Trans. Power (W)	Antennae	Comments
L-Band (Maritime)	4.0	200	Four 3 m dia.	Oceanic coverage
VHF (Aero)	0.55	100	One 10 m dia.	Global coverage
L-Band (Aero)	15.0	100	One 1 m dia.	Global coverage
800 to 900 MHz* (Land Mobile)	6.0	320	Four 12 m dia.	Four spot beams each covering one CONUS time zone

Total peak power = 300 W*
Total prime power requirements = 1.0 kW

* Because of the preliminary nature of this application, it is omitted from the totals and spacecraft descriptions.

shown in fig.7. The channelled sections are interconnected by cross members to form a girder having a triangular cross-section one metre in depth. The ends of the girders have a rigid, quick connect fitting. Six of these girders can be assembled in space to form a tetrahedron, and these in turn can be quickly assembled into a complete structure.

Payloads can be clamped on either side using quick connect clamps. Overall dimensions of the platform are 62 m long, by 47 m wide and 12 m deep.

Onboard Propulsion System

The attitude and stationkeeping requirements are predicted on the intent to replenish the geosynchronous station every five years. During this period the reaction control system (RCS) will be required to

- Correct for injection errors.
- Unload the momentum of the reaction control wheels of the stabilisation subsystem.
- Correct for North-South drift within 0.5 degree latitude.
- Correct for East-West drift within 0.5 degree longitude.

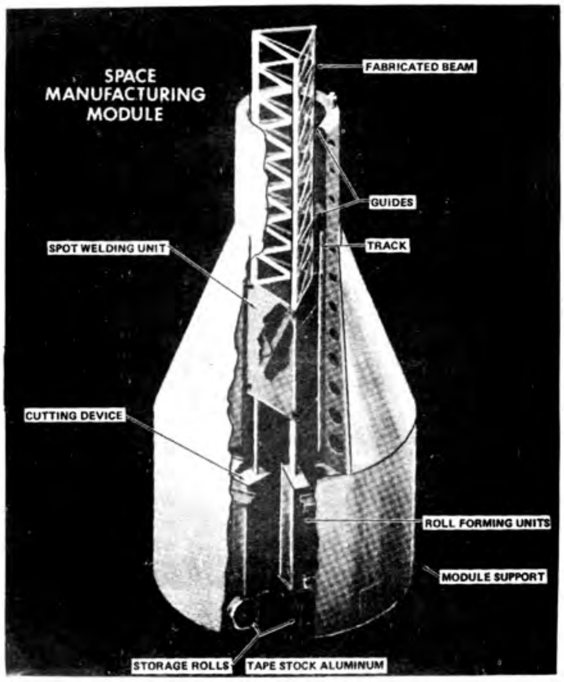


Fig. 7. Space manufacturing module.

- Provide contingency—getting on station, changing position, etc.

East-West stationkeeping requires a delta-V correction about every forty days of 0.18 m/s (0.6fps) or a total of 9.14 m/s (30 fps) over a five year period. North-South drift would be approximately 0.853 degree per year and would require correction every fourteen months. Approximately 53.6 m/s (176 fps) would be required three times during a five year period or about 106.7 m/s (350 fps) total for a five year period.

The system was sized using Hydrazine (N_2 H_4) as the propellant in a blow-down system. Total impulse allowed for each task with a specific impulse (I_{sp}) of 228 sec is:

East-West stationkeeping	=	9.14 m/s (30 fps)
North-South stationkeeping	=	161.5 m/s (530 fps)
Momentum unloading	=	15.1 m/s (50 fps)
Trim positioning	=	76.2 m/s (250 fps)
		259 m/s (850 fps)

The weight of propellant is determined by:

$$W_p = \frac{\Delta V M}{I_s} = 962 \text{ kg (2121 lb)}.$$

Redundant thrusters are mounted on the four corners of the rectangularly shaped platform as depicted in fig. 8. Total weight of the fuel and hardware based on flight qualified hardware is estimated at 1555 kg (3428 lb). This would change, of course, with any changes in payload or space platform subsystem mass changes.

Alternate propulsion systems were studied and by the time of final system configuration, either Cesium or mercury ion engines may be used for North-South stationkeeping and momentum wheel unloading. With a mercury ion engine system, total engine weight would be 127 kg (280 lb) plus 90.7 kg (200 lb) for fuel or 217.7 kg (480 lb) total. A separate, small pulsing capability loaded with 31.8 kg (70 lb) of N_2 H_4 systems, consume a large amount of electrical power. Each of two engines would consume 1100 watts for

TABLE 5. Broadcasting Satellite Service Characteristics

Carrier Freq. (GHz)	Band-width (MHz)	Peak Trans. Power (W)	Antennae	Comments
2.535 to 2.655	120	400	1 x 3 m*	CONUS coverage
12.3 to 12.5	300	500	0.20 x 0.60 m Horn	CONUS coverage
12.2 to 12.5	300		Three 1.5 m dia.	

Total primary power requirements = 2.5 kW

* Multiplexed with S-band fixed satellite communications.

TABLE 6. Characteristics of the Space Research, Earth Resource, and Meteorological Satellite : Communications on the Platform

Carrier Freq. (GHz)	Band width (MHz)	Peak Prans. Power (W)	Antennae	Comments
TDRS				
S-Band				
XMT (2.2 to 2.3.)		10	Two 3-m dia.	Platform to spacecraft
RCV (2.025 to 2.120)				Spacecraft to platform
RCV (2.2875				Spacecraft to platform
XMT 2.107		10		Platform to spacecraft
K Band				
RCV (14.6 to 15.25)*			**	E/S to platform
XMT (13.775)	1.4	10		Platform to spacecraft
SMS				
RCV 0.4019	0.4		Phased array	DCP to SMS
XMT 0.468825		40	Phased array	SMS to DCP
RCV 2.03 to 2.034	8		Switched dipoles	
XMT 1.68 to 1.69	23.2	20	Switched dipoles	Telemetry and weather reports

Total primary power requirement = 400 w

* This could be replaced by fixed satellite communications links to E/S

** Located on the feed of the 3-m dia S-band antennae.

six hours each day; however, the advantage of weight reduction far offsets the increased power requirement.

Spacecraft Power

NASA would provide a 5-percent voltage regulated solar array bus with sufficient battery capacity to accommodate all commercial operating requirements during eclipse, except high powered TV broadcast. The user would provide the means to regulate more precisely if required. Stationkeeping manoeuvres might be performed to best advantage when the communication traffic power requirements are at a minimum so that if any attitude perturbations result, the effect on traffic on spot beams would be minimised.

Advances in the areas of lightweight roll-out solar arrays and standardised batteries having 100 ampere-hour cell capacity should also be available.

The system is divided into two unregulated busses – a high voltage (200-volt) high power bus for major loads (communication system) and a low voltage (28-volt) low power bus for the spacecraft support systems (altitude control, telemetry and command, etc.). Individual regulators are required for each high power load, while a central bus regulator is used for the support systems.

A 200-volt distribution system is proposed to minimise the power harness loss and reduce the harness weight. The system must supply a communications load of up to 20 kW. Table 8 shows a breakdown of the power requirements. Note that the communication equipment, including contingency, uses 12 kW from the 200-volt bus.

Solar Array

To meet these load demands, the solar array will be designed to supply an end-of-life (five years) power of 16.25 kW. Based on a cell-cover-glass design to limit radiation and environmental power degradation to 18 percent in five years, a beginning of life power of 19.0 kW results.

TABLE 7. Load Power and Array Power Requirement

Power for communication equipment	8.81 kW
Power for support systems	1.0 kW
Contingency	3.19 kW
	12 kW
Conditioning/regulation/distribution Losses (87% efficiency)	1.95 kW
TOTAL LOAD REQUIREMENTS	14.95 kW
Worse case beta angle effect on array output (23½°)	1.3 kW
EOL array capability	16.25 kW
Degradation 18%/5-years	3.57 kW
BOL array capability	19.8 kW

The total array cell area required to provide a beginning-of-life power of 19.8 kW is 165 square metres. The proposed design would use two wings each consisting of 82.5 square metres of cell area. The actual wing size would depend largely on the dynamic interactions with the attitude control system and spacecraft stability and pointing requirements.

Each array wing would require a drive mechanism to maintain the array in a Sun-pointing attitude. In addition, the array design would provide for retraction and extension as necessary to satisfy the load requirement and limit excess power dissipation.

Battery

The batteries will be sized to accomodate commercial communications, (except for Earth observation sensors, meteorological sensors, and TV broadcast services) and pro-

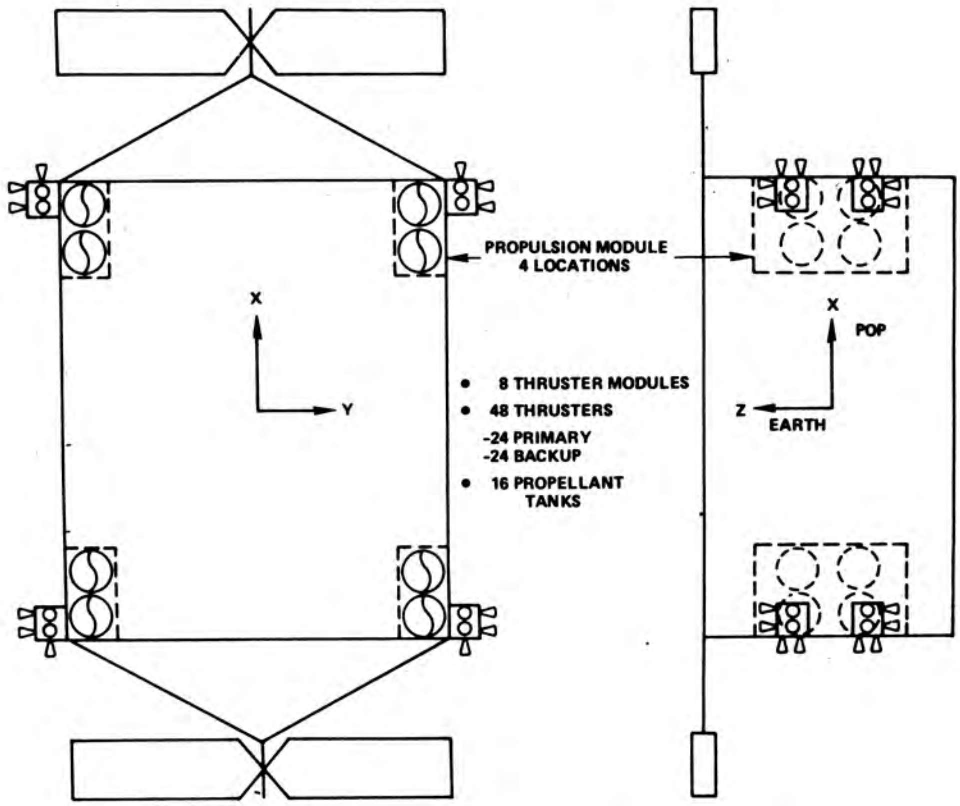


Fig. 8. Stationkeeping and attitude control propulsion system location.

sor error voltages would be available at nearly all mounting vide spacecraft support system power during eclipse operation. Assuming a maximum acceptable depth-of-discharge of 40 percent for a five year mission, 6 kW hours would be required. If we assume the use of the NASA Standard Battery with 50 ampere-hour cells, twelve batteries (having 22 cells, 50 ampere-hour each) would provide 6 kW hours for the 72 minute maximum eclipse. Three additional batteries should be used for constingency, making fifteen total. Each battery weighs approximately 46 kg (100 lb); therefore, the total battery weight would be 690 kg (1500 lb).

Stabilisation and Pointing

NASA would provide continuous Earth pointing of the platform to within ±0.5 degree by use of Earth sensors to provide the error inputs to the three-axis stabilisation system. Antennas, camera or censor apertures requiring vernier pointing precision would be provided by the user. Earth sensor locations and these would provide pointing precision to ±0.1 degree.

The four-reaction-wheel stabilisation system provides equal momentum storage per axis of 35.8 N : m/s with a skew angle of 63.4^0. Each wheel weighs 10 kg requiring 75 W at full torque of 0.3 N·m. It is planned to unload momentum once per 24 hours with the RCS.

Telemetry and Command of Communications Payload

Commercial communication payloads and NOAA meteorological and other data collection of Public Service user payloads would be responsible for their own telemetry and command systems which they would control from their own communications and control centers.

If certain users desired a backup telemetry and/or command capability, NASA could provide a remote interface unit for this purpose.

TABLE 8. Geostationary Communications Platform : Mass Characteristics (30-Metre Antenna)

Description	Weight (lb)	XCG (ft)	YCG (ft)	ZCG (ft)	IX slugs ft 2	IY slugs ft 2	IZ slugs ft 2
0.7 x 2 Ellip Refl	58	44.29	-76.71	3.28	5	1	6
30 m Cir Refl	1219	0.00	0.00	3.28	22944	22944	45881
12 m Cir Refl	180	44.29	76.71	3.28	543	543	1086
4.5 Cir Refl	75	-73.82	25.57	3.28	32	32	64
4,5 Cir Refl	75	-73.82	-25.57	3.28	32	32	64
4.5 Cir Refl	75	73.82	25.57	3.28	32	32	64
4.5 Cir Refl	75	73.82	-25.57	3.28	32	32	64
Small Horn	110	88.59	0.00	2.50	1	1	1
2 Cir Refl	54	14.76	76.71	3.28	5	5	9
1 x 3 Ellip Refl	116	14.76	-76.71	3.28	22	3	24
3L Refl	234	-29.53	51.14	3.28	44	44	87
3L Refl	234	-29.53	-51.14	3.28	44	44	87
3L Refl	234	29.53	51.14	3.28	44	44	87
3L Refl	234	29.53	-51.14	3.28	44	44	87
10 m VHF Refl	235	-44.29	-76.71	3.28	492	492	982
1 m L Refl	49	-14.76	76.71	3.28	1	1	2
1.5 m Cir Refl	30	-14.76	-76.71	3.28	1	1	3
1.5 m Cir Refl	30	-59.05	-51.14	3.28	1	1	3
1.5 m Cir Refl	30	-44.29	76.71	3.28	1	1	3
0.2 x 0.6	154	0.00	51.14	3.28	1	1	1
Phased Array	184	59.05	0.00	2.50	12	6	17
Phased Array	184	-59.05	0.00	2.50	12	6	17
3 m Cir Refl	173	59.05	51.14	3.28	33	33	65
3 m Cir Refl	173	-59.05	51.14	3.28	33	33	65
5 m Cir Refl	300	59.05	-51.14	3.08	158	158	313
Batteries	1592	0.00	0.00	-34.45	21	6	19
Solar Array	275	-103.35	30.00	0.00	1198	183	1380
Solar Array	275	-103.35	-30.00	0.00	1198	183	1380
Solar Array	275	103.35	30.00	0.00	1198	183	1380
Solar Array	275	103.35	-30.00	0.00	1198	183	1380
ACS	760	0.00	0.00	-34.45	10	3	9
TCC	410	0.00	0.00	-34.45	5	2	9
RCS (Double Mod)	857	-73.82	42.92	-10.51	71	104	71
RCS (Double Mod)	857	-73.82	-42.92	-10.51	71	104	71
RCS (Double Mod)	857	-73.82	42.92	-10.51	71	104	71
RCS (Double Mod)	857	73.82	-42.92	-10.51	71	104	71
Main Structure	5164	0.00	0.00	-11.19	323418	420560	726814
Support Structure	1100	0.00	0.00	-34.45	192	192	241
Total Geo Comm Plat	18069	1.43	-0.06	-11.76	965636	1737749	2489430

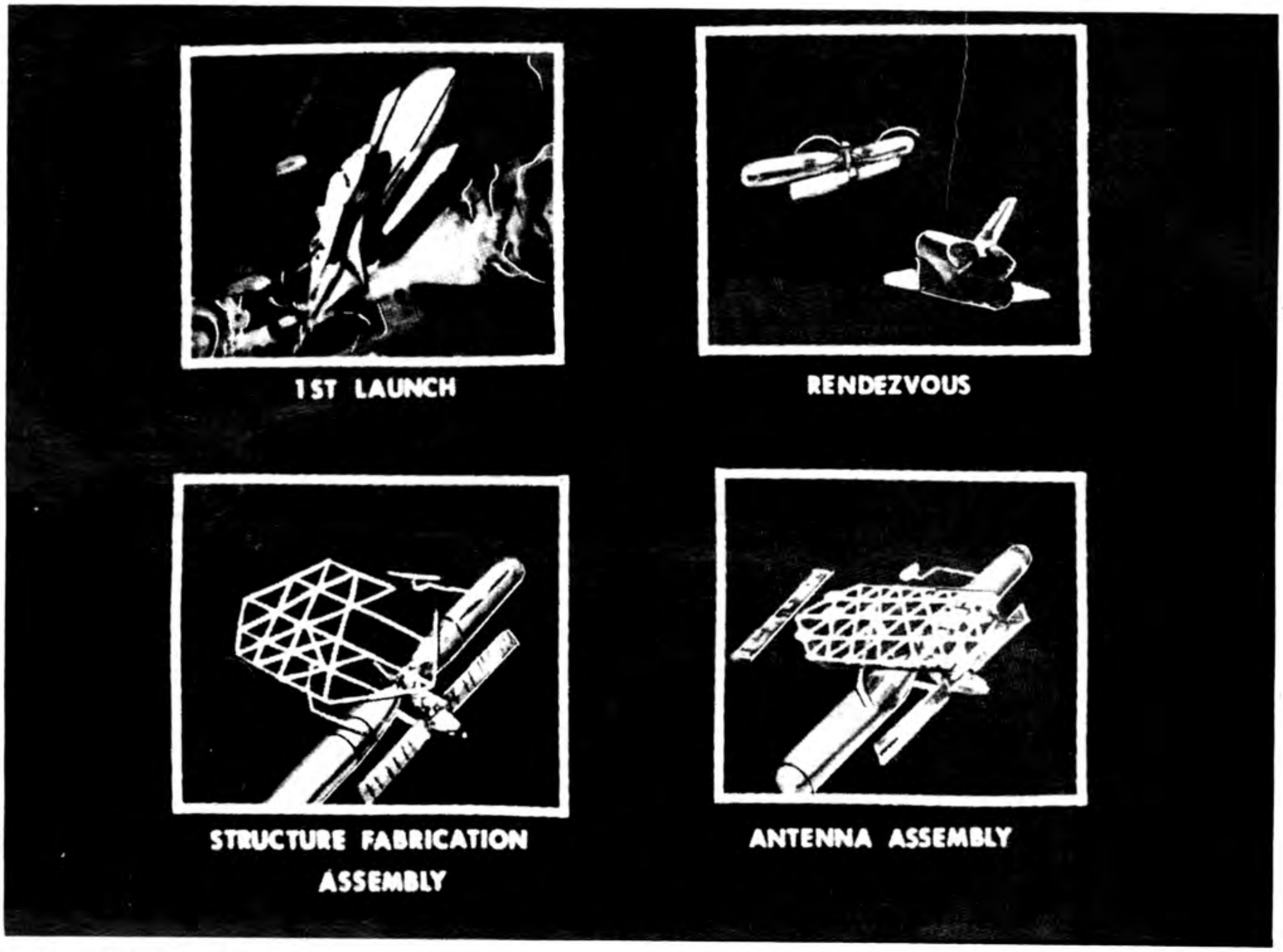


Fig. 9. First payload and assembly.

Stationkeeping Communications and Data Handling

The Communications and Data Handling Subsystem provides a means for tracking, for ground and onboard command control of all spacecraft equipment operating and monitoring functions, and for transmission of housekeeping and low-bit-rate instrument or sensor data from technology and scientific experiments. A NASA standard S-band transponder can be used for ranging, receiving commands, and for transmitting narrowband sensor and housekeeping data.

Launch Sequence and Platform Assembly

The space platform, as presently conceived, will require three shuttle launches to complete its assembly and mount the users equipment. The approximate mission mass properties for these three flights are provided in Table 8.

It is proposed that the assembly of the first, second, and third loads occur in a circular low-Earth orbit at an altitude of 500 km inclined to the equator at 28 degrees with a period of 95 minutes. This orbit is a nominal orbit for the space shuttle operations.

The first shuttle payload (fig. 9) will consist mainly of the 30-m diameter antenna (fig. 10), its forty (or more) spot-beam feed, and sufficient platform structure to provide power and docking facilities for the second and third shuttle launches.

After the structure, 25-kW solar array and communications equipment are assembled in orbit using a pair of manipulating arms, the antennas are deployed and checkout is completed. Orbiter number 2 undocks and returns to Earth for the third load which consists of the orbital transfer vehicle (OTV) and the space platform support module. This module contains more antenna, batteries, the platform attitude control system, the telemetry and command system and the reaction control system.

Approximately twelve weeks after the second shuttle has returned home, the third shuttle is launched. It manoeuvres and redocks with the platform and completes the unloading and assembly process. The total assembly time in orbit of the first and second shuttle mission is sixty days and seven days for the third shuttle mission.

When the platform is fully assembled and checked out, the solar arrays are retracted and the liquid hydrogen-oxygen fueled (OTV) injects the platform to the Hohmann transfer ellipse. At the synchronous altitude the OTV engines are restarted and the space platform is injected into the geostationary orbit. The OTV is undocked and returns to the low-Earth orbit and is picked up by the shuttle. The deployment of the solar arrays and remaining antennas is initiated and observed on ground monitors or platform television cameras.

Commercial services can begin after thorough and satisfactory checkout of all space platform subsystems is completed and sufficient time for outgassing has elapsed.

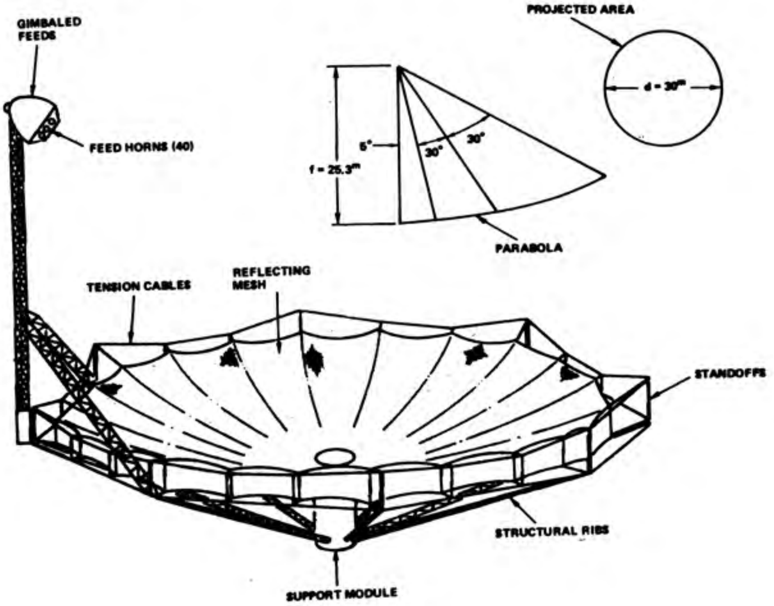


Fig. 10. 30-metre antenna.

Right. Fig. 11. Docking module.

Platform Replenishment

The conceptual design of this GCP provides a docking module (fig. 11) for revisits by the OTV every five years on the average.

Essentially every spacecraft subsystem should be designed with the intent to either replace, repair or add to, and designs should include provision to enlarge the platform structure. The spacecraft power bus should provide cabling to future interface connections and terminated so that structure and payload add-ons could have ready access to power and Earth sensor signals for precision pointing.

Every revisit to the platform station would include provision for reaction control modules. In some cases a new transponder with increased capacity and flexibility might replace an existing one that has either failed or become obsolete. A revisit might include any reasonable number of science and technology experiments that could be placed on the structure and not interfere with antennas on the Earth viewing surface of the platform. Carriers probably would want to replace their transponders, switching gear, and possibly some of the antennas.

After ten year intervals NASA would probably desire to replace solar array casettes and stabilisation modules with more efficient systems.

Accommodation of Commercial Services

Fixed (Point-to-Point) Communications

C-Band

The primary use of communications satellites to date has been as point-to-point trunk lines, competing with underseas cables in the case of Intelsat, and with cross country microwave or coaxial circuits in the case of domestic satellites. Ten individual domestic satellites are currently in geostationary orbit in view of the United States and Canada. These ten satellites all share the same C-band radio spectrum (5935 MH_Z to 6425 MH_Z up, and 2700 MH_Z to 4200 MH_Z down). Competition for the choice orbital slots, (approximately 105 to 130 degrees West longitude) providing a view from Maine to Alaska, is intense.

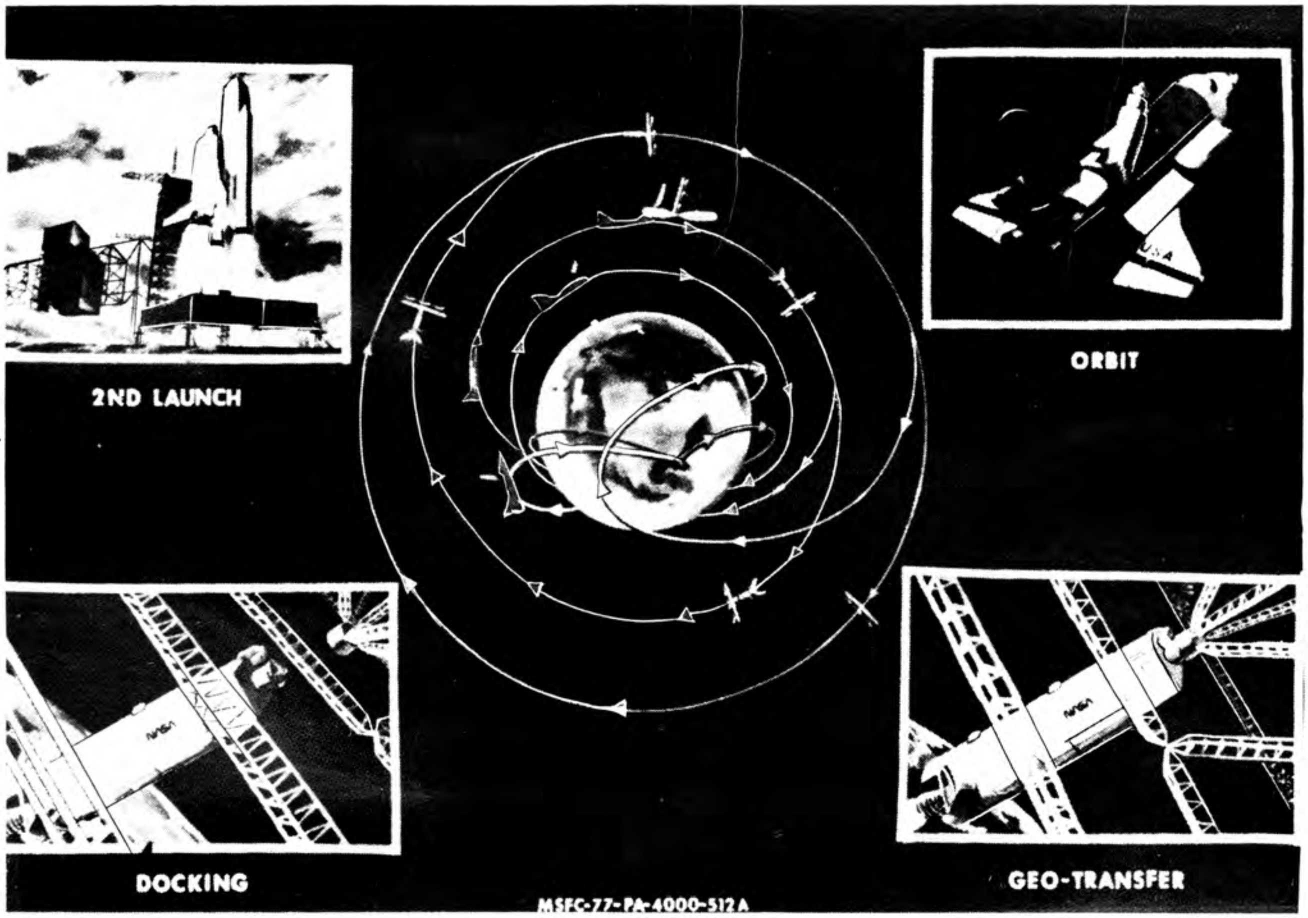
To avoid mutual jamming by adjacent satellites, they have been assigned orbital positions 4 degrees apart in the geostationary orbit. The principle means of discrimination against interfering signals from neighbouring satellites is the narrow beamwidth of the Earth station's receiving antenna. Initially, the FCC required E/S antennas no smaller than 9-m in diameter which restricts the half-power beamwidth to 0.6 degree. Recently, the receive-only E/S with diameters as small as 4.5 m are processed routinely. These antennas have beamwidths of 1.3 degrees, which can discriminate against satellites 4 degrees apart.

This concept is designed to provide the same capability from a single platform as is now available from the six United States domsats with 120 (36-MH_Z) transponders. These six satellites all transmit in the 3.7 GH_Z to 4.2 GH_Z band, and provide six overlapping antenna footprints covering the CONUS. The E/S discriminate between these satellites by focusing their antenna beams upon single satellites, and also by using orthogonal polarisations to double the capability of the allocated 500 MH_Z of bandwidth.

If these 120 transponders are concentrated on a single platform, multiple spot beams can replace the discrimination formerly provided by orbital spacing. This can greatly expand the growth potential because the allocated frequency spectrum can be re-used in each spot beam.

The platform could accommodate two C-band, broad-beam antennas (4 degrees by 8 degrees, formed by a 0.7 x 2-m ellipsoidal reflector) which are cross-polarised and cover the entire CONUS. These wide-area coverage antennas could use the upper half of the 500-MH_Z spectrum available at C-band with time division multiple access (TDMA) modulation so that any E/S could communicate with any other E/S in the wide-area footprint.

The lower half of the C-band allocation could be used many times over in multiple spot-beam antennas. At 4 GH_Z, this antenna could use multiple feeds with a reflector 30 m in diameter. The footprints of these spot beams would encompass the largest metropolitan areas that are communications centers, and serve as trunking circuits to augment and replace terrestrial trunk lines. Forty separate spot beams are envisaged, along with three additional offset feeds on this large reflector to provide coverage of Hawaii, Alaska, and Puerto Rico.



The power flux density (pfd) in these C-band footprints would be comparable to that now supplied by the current domsats (e.g., -130 dBW/m^2), so that E/S antenna diameters of4.5 m are adequate to receive video signals. The platform C-band transmitters must be approximately 250 mW for the spot beams, and 40 W for the wide-area beams.

Ku-Band

The Ku-band transponders (12/14 GH$_z$) are permitted to lay down higher pfd than the C-band. For this reason, they are better suited for communications with small terminals (except possibly during rainstorms). Multiple feeds on a single 12.0-m diameter reflector can form twenty spot beams that cover the twenty large metropolitan communications centers. Each spot beam will cover a footprint approximately 200 km in diameter. Small roof-top antennas (1.5 m in diameter) within these footprints can access the satellite.

An additional four independently-gimballed 4.5-m diameter Ku-band antennas can cover areas of interest that may be outside the top twenty metropolitan centers. These antennas can be focused upon smaller cities for coverage of news and sporting events.

To reach small (3-m diameter) Earth stations, a power output of 4 W in each beam is adequate. The fixed communications service can use the frequency band from 11.7 GH$_z$ to 12.2 GH$_z$ in the downlink. Cross-polarisation can be used to avoid interference in adjacent footprints. The power output of these Ku-band transmitters is 120 W.

K-Band

The 30/20-GH$_z$ transponders are currently in the experimental stage. The 3.5-GH$_z$ total bandwidth in this allocation is seven times greater than the C-band allocation currently used by all commercial communications satellites. This provides a tremendous potential, but could be hampered by water vapour attenuation. It might be a good solution for the transmission of data and electronic mail when real-time duplex communications are not required. A wide-area beam covering the CONUS could be used with a TDMA system for wide bandwidth data communications. A small horn antenna would suffice; a high power transmitter with a total output of 1 W will be necessary to make use of the total bandwidth and provide enough signal margin to override some water vapour attenuation. These transponders could also be used for experiments in personal communications (between portable hand-held walky-talkies). To provide more signal power and sensitivity for these applications, ten feeds could form ten spot beams on a 2-m diameter reflector to cover major metropolitan areas.

S-Band

Two 35-MH$_z$ bands are allocated for thin-route point-to-point communications (2500 MH$_z$ to 2535 MH$_z$ down, 2665 MH$_z$ to 2690 up) between small terminals. A 1 x 3-m antenna can provide CONUS coverage at S-band. In order to communicate with 3-m diameter E/S antennas, the satellite power output should be on the order of 75 W per video

channel. A power output of 100 W can permit a limited number of voice channels as well.

Mobile Satellite Communications Service

Communication with mobile terminals over wide areas represents a service that can be provided reliably and uniquely by satellites. The point-to-point communications can be provided by terrestrial communications as well as by satellite, particularly along major trunk lines. Communications to far-ranging ships and aircraft has been provided by HF radio, which is narrow-banded and subject to static resulting from thunderstorms and ionospheric disturbances. Satellite communications offer a clear advantage that has been demonstrated experimentally and operationally by Marisat.

L-Band Communications (1500/1 600 MH_Z)

The Marisat uses L-band between the ships and the satellite, and C-band between the satellite and two E/S. Terrestrial links carry the signals between the land-based terminal and these E/S. The planned Marots is similar. The platform offers a clear advantage in this application because any E/S in view can communicate with the platform, and onboard switching circuits can make connections to the L-band link to the ships. This obviates the need for dedicated E/S and shortens the terrestrial links from the land-based terminal to the dedicated E/S.

The ship-borne terminals now require an antenna slightly larger than 1 m diameter. The narrow (10-degrees) beam from this antenna requires a gyro stabilised mount. If more antenna gain were available on the platform, a wide beam hemispheric coverage antenna could be used on the ships at a greatly reduced cost. The gain could be made up by the use of multiple 3-m diameter dishes on the platform in place of the quad-helix array on the Marisat. Eight such dishes could provide complete coverage of ships visible from the platform.

The Marisat L-band transmitters have a total output power of 10 W. The platform L-band transmitters' power output is 100 W. The UHF links from the Marisat to Navy ships, or any military communications, are not considered for the platform.

VHF and L-Band Communications with Aircraft

The ill-fated Aerosat was terminated primarily because of the high costs. The costs could be substantially reduced if the Aerosat transponders were incorporated into the platform. The link between the E/S and the satellite were C-band. These are incorporated in the platform for fixed satellite communications. The links between the satellite and the aircraft included both VHF (126/132 MH_Z) and L-band (1.5/1.6 GH_Z). Earth coverage beams at these frequencies will require 10-m and 1-m diameter antennas, respectively.

UHF Communications with Land Mobile Vehicles

A promising service that has been tried experimentally is communications with land mobile vehicles over wide-spread areas. The link between the platform and the vehicles might use either UHF (near 800 MH_Z) or L-band. Four feeds illuminating a 12-m diameter reflector could provide coverage over the CONUS and Canada to small terminals with hemispheric coverage antennas in trucks and cars. Four 80-W transmitters would be needed. Signals from these vehicles could be switched to the fixed communications service transponders on the platform.

Broadcasting Satellite Service

Broadcasting satellites radiate high power flux densities that can be received by many small cheap receivers over wide areas on Earth. This service was pioneered by NASA's ATS-6 at 860 MH_Z (to India), and at 2.5 GH_Z (in the U.S.). The CTS, a broadcasting satellite sponsored jointly by NASA and Canada's Communications Research Cenre, broadcasts at 12 GH_Z to E/S antennas with diameters as small as 60 cm. Future 12-GH_Z broadcasting satellites include Japan's BS, and ESA's Orbital Test Satellite (OTS). No follow-on satellites are currently planned at S-band (2500 MH_Z to 2690 MH_Z).

The platform could include S-band broadcasts of educational television to continue the work begun at ATS-6. To reach the current 10-ft diameter E/S antennas, the platform could use a 1 x 3-m antenna for CONUS coverage with a 400 W transmitter. The total prime power requirement would be 1 kW. The uplink could use any of the Earth-to-space links cross-strapped to the S-band transmitter.

The broadcasts at Ku-band must co-exist with the fixed satellite service. These services cannot easily share this band and the simplest solution may be to divide the frequency spectrum between the two services. To illustrate, suppose the broadcasting transmitters use 12.2 GH_Z to 12.5 GH_Z , and the fixed satellite transmitters use 11.7 GH_Z to 12.2 GH_Z. To provide CONUS coverage, a small horn antenna (20 x 60 cm) and a 500-W transmitter will suffice. Additional horn antennas can focus spot beams on areas of interest outside the CONUS.

Meteorological/Earth Observations

Present plans include U.S. launch and operation of two geosynchronous meteorological satellites nominally stationed at 75^{0}W and 135^{0}N through the early 1980's at least. These satellites will cover the Earth's disc from the mid-Pacific to the mid–Atlantic and the land masses between. Sensors are planned to provide visible and infra-red photographs of the Earth's disc as well as vertical soundings of the atmospheric structure.

It is envisioned that the platform could readily accommodate an equivalent sensor payload and larger aperture sensors that would provide greater resolution.

In addition to the visible and infra-red photography it is proposed to include a microwave atmospheric sounding imagining radiometer (AASIR). The MAS will measure the temperature and humidity profile of troposphere and lower stratosphere and measure cloud distribution. It will use a large (4- or 5-metre) scanning reflector operating at discrete frequencies from 50 GH_Z to 190 GH_Z. The AASIR will provide high resolution temperature and humidity profile, and determine cloud distribution, height, and wind velocity. It will be a multichannel visible/infra-red scanning radiometer.

Other sensors to measure the Earth's infra-red budget and atmospheric pressure are under consideration and may be included on this platform eventually.

The Earth Exploration Satellites (Landsats) use a low-Earth, Sun-synchronous orbit and hence are not candidates for inclusion on the platform.

Other Service Opportunities

Navigation, Ship Surveillance, Search and Rescue, Data Collection

Today there is an ever increasing number of small vessels using satellite navigation systems. The U.S. Coast Guard is actively pursuing the early use of satellites to aid in search and rescue, to monitor the 200-nautical mile Coastal Zone, and to prevent tankers from colliding with other ships

or grounding in shoals and breaking up. The retrieval of all types of data from *in-situ* in forests, rivers, lakes, glaciers, fields, volcanoes, and those data from moored and drifting buoys, is heading toward the predictable "data explosion". The platform provides a low cost means of accommodating all of these requirements.

This very large structure makes the interferometer approach more attractive for navigation and position location. A 100-metre baseline, with continuous LASER calibration to compensate for automatic length and deformation changes, might provide a very accurate navigation system.

Public Service

Quite apart from the services already provided by existing domestic satellites, there are many other services that have been tested and tried but not implemented on a regular basis. There are many U.S. citizens in remote areas who do not have access to telephone or television services and who are unable to receive sufficient warning of disasters or receive up-to-date medical services. It would also be possible to provide educational classroom instruction to naval personnel, fishermen, and offshore platform station attendants who spend months at sea.

Technology Experiments

The principal technological developments needed for the platform are: (1) high capacity, onboard switching and multiple-access systems, and (2) variable multiple contoured beam forming antennas. The orbiting of a "switchboard-in-the-sky" is in the conceptual stage. The ATS-6 and Intelsat-V can cross-strap signals between different transponders and antenna beams, but the platform must be able to handle a large number of burst data streams in store and forward circuits controlled by addresses in the signals or by ground commands. The signals may require demodulation and remodulation having much greater complexity than the "bent-pipe" transponders used to date.

Conclusion

The use of the Shuttle for achieving a large geosynchronous communication satellite is a potentially attractive pursuit. Quite obviously, much more conceptual planning is needed and should be based on the opinions and needs of communications carriers and other agencies.

At this time it is not possible to provide an accurate cost-benefits comparison with present satellite systems without more detailed study and information. It is apparent, however, that a twenty-year platform life expectancy, using shuttle revisitations to update onboard systems, has the potential of reducing costs not only of the communications carriers but also of the government's meteorological and other public service programs. Certain of these services, requiring very large apertures or structures cannot be done by conventionally launched free-flying spacecraft. In these applications it is very difficult, if not impossible, to achieve these services or capabilities without the Shuttle.

NASA will continue studies leading to a definitive program plan for achieving a "Switchboard in the Sky."

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SPACE REPORT

A regular monthly review of Space Events and Technical Trends

FAR SIDE MOON MAP

The Moon's far side has been mapped in great detail by the Moscow Institute of Geodesy using photographs obtained by Zond circumlunar spacecraft. On a scale of 1:1,000,000 on Mercator's projection, the map covers 10 sheets.

The map gives a clear idea of far side features including mountains, craters, depressions and other irregularities. *Novosti* says it will be of great help in further study of the Moon and will be invaluable to cosmonauts landing on or circling it.

MAPPING PRIMEVAL COSMIC MATTER

Professor Peter Willmore, Head of the Department of Space Research at Birmingham University, has now heard that his Department's experimental programme with its own version of the coded mask X-ray telescope will have a place onboard Spacelab Two, writes Patrick Dowling. It is one of several hundreds considered by NASA and will occupy one quarter of the total available accommodation.

Professor Willmore's own interest in the properties of the various masks and their applications to X-ray telescopy is of ten years standing and will culminate in the Spacelab Two mission, scheduled for 1981. Eighteen months ago his Department took the first pictures in X-ray of the galactic centre using a coded mask, and it is currently involved in Ariel 5 (see *Spaceflight*, February 1978, pp. 42-47). Birmingham's own patent is the pseudo-random mask which can work at any wavelength but which has properties especially suitable to the study of short wave emissions.

The high X-ray activity that the Department are anxious to study is almost certainly from the distant galaxies and of the order of 10,000 times the magnitude of the total X-ray emissions of our own. The gas in which the galaxies are immersed has two possible sources. It is either primeval matter left over from the Big Bang or it is material that has leaked from the galaxies and in the latter case it will be traceable by iron line emission.

Professor Willmore's own feeling is that observation will

reveal iron-line emission round certain galaxies and the Department have developed a filter to permit the exclusive plotting of iron-lines which in its turn will help them locate and map the primeval matter by a process of deduction.

The technique's newness, its planned re-flight potential of ten and its relatively large size (three telescopes are involved) make the experiment a very economic use of the Shuttle which, Professor Willmore suggested, probably impressed NASA most of all. Currently the Department is working on design. The equipment will be built on-campus and is scheduled for completion in mid-1979 and transportation to the United States in 1980.

The Department will be mounting its own 12-man observatory at NASA's payload operation control centre. They will thus be able, during the actual mission, to monitor readings and if necessary, using mini-computers set in the pallets of the Shuttle's loading bay, to vary the site of observation. The team will be in touch *via* mission control with the astronauts who will be trained to instruct the telescopes daily to a pre-planned programme and to change it, should the need arise.

SPACE PROCESSING HARDWARE

More 'space factory' experiments are being prepared for astronaut payload specialists to perform aboard the Space Shuttle Orbiter in mid-1981. Under micro-gravity conditions in Earth orbit, sedimentation in liquid materials is eliminated and movement of fluid caused by heat is reduced, allowing precise control of processes such as casting and crystal growth.

Another promising example is the separation of live kidney cells tested during the Apollo-Soyuz mission in 1975. The separated cells produced urokinase, an enzyme used to dissolve blood clots, at a much greater rate than that of mixed kidney cells in the ground control specimens.

Under NASA's Materials Processing in Space (MPS) programme, the Marshall Space Flight Center in Huntsville, Alabama, has asked industry to submit proposals for eight experiments to be flown on 1981 Shuttle/Spacelab missions. Items to be developed include a fluids and a solidification experiments system with a high-temperature furnace. Other hardware systems supporting individual experiments also will be developed together with related Earth-based systems.

The first experiment will accommodate a variety of experiment cells for testing a broad range of fluids, using optical observation techniques.

The solidification experiments system will provide a multi-use system for conducting MPS experiments with many types of metals, alloys, eutectics, semiconductors, crystals, ceramics, glasses, etc., by melting, refining and resolidification in the near weightlessness.

A "ground control" laboratory housing flight-related hardware systems, to be installed at Marshall Center, will allow scientists to process "control samples" under identical conditions, except for the gravity level, to those to which the experiments were subjected during processing in Earth orbit. The lab may also be used to train payload specialists who will perform the experiments in space.

Two experiments will be conducted in the fluids system during the third Spacelab mission: "Solution Growth of Crystals in Zero-Gravity." (Principal investigator is) Dr. R. B. Lal of Alabama A&M University in Huntsville, Alabama. "Crystal Growth in a Spaceflight Environment." Paul J. Shlichta of NASA's Jet Propulsion Laboratory, Pasadena, California.

The six experiments to be conducted in the solidification system are: "Semiconductor Materials Growth in Low-G Environment." R. K. Crouch of NASA's Langley Research Center, Hampton, Virginia; "Growth of Solid Solution Single Crystals." Dr. Mirt C. Davidson of NASA's Marshall Space Flight Center; "Liquid Miscibility Gap Materials." Dr. S. H. Gelles of Gelles Associates, Columbus, Ohio; "Aligned Magnetic Composites." Dr. J. Larson of Grumman Aerospace Corporation, Bethpage, N.Y., and "Solid Electrolytes Containing Dispersed Particles." J. Bruce Wagner of the Center for Solid State Science, Arizona State University, Tempe; "Vapour Growth of Alloy-Type Semiconductor Crystals," Heribert Wiedemeier of Rensselaer Polytechnic Institute, Troy, N.Y.

Other principal investigators will be selected later for follow-on experiments in the MPS apparatus.

MOON SOIL TEACHING AID

The National Aeronautics and Space Administration has developed a new lunar and planetary sciences teaching aid using actual samples of lunar material encased in a clear plastic disk. The new aid is aimed at both the Earth science student through the Aerospace Education Program and the museum visitor through the NASA exhibits programme.

The sample disk will be used as the basic component in both programmes and is designed to be hand held so that both sides of a sample can be seen and, because of the clear plastic encasing, viewed through a microscope for greater resolution of the samples themselves.

The packets are designed to extend the lunar and planetary science education programmes which have been developed by NASA over the past eight years. Presently, colleges can borrow thin-section microscope slides of lunar material. These thin-section kits include an extensive teaching manual and present lunar and planetary science material at a level appropriate to university petrology and mineralogy classes.

In addition to the thin-section kits, NASA has several dozen representative lunar samples prepared in display cases for exhibition at state fairs and museums.

Up to now there has been no programme using lunar material which has been aimed at the secondary Earth science student or the more curious science museum visitor. Many high schools and several museums throughout the United States have innovative and entertaining "hands on" science classes and displays which invite participation. The new lunar sample educational packets are aimed for these audiences.

The programme designed for high school Earth science audiences will include a film on lunar science, the sample disk, workbook material, slides,an audio cassette, and will involve considerable interaction between the teacher and the class. The museum programme will use a shorter sound-slide presentation and the disk. Both programmes involve the student directly by means of the student's close examination of the samples and the interactive nature of the teacher's discussion material.

Student reaction to the material has already been tested using students at Houston-area and Lincoln, Nebraska, high schools. Reaction from both students and teachers has been extremely favourable. Museum visitor reaction will be tested early this year when eight prototype museum kits will be sent to the following museums: Pacific Science Center, Seattle, Washington; Oregon Museum of Science and Industry, Portland, Oregon; Palace of Arts and Science Exploratorium, San Francisco, California; Lawrence Hall of Science, Berkeley, California; Des Moines Center for Science and Technology, Des Moines, Iowa; Cranbrook Institute of Science, Bloomfield Hills, Michigan; Maryland Academy of Sciences/Maryland Science Center, Baltimore, Maryland; and the National Air and Space Museum, Smithsonian Institution, Washington, D.C.

The sample disks are methacrylate plastic, six inches in diameter, one-inch thick, and contain a one-half gram sample of each of the following lunar soil types: Lunar breccia (a broken surface soil type); a lunar basalt (solidified

volcanic matter); a lunar anorthosite (an igneous rock composed of calcium, aluminium, silicon, and oxygen); a sample of the Moon's orange glassy soil; a sample of lunar Mare soil; and a sample of lunar Highland soil.

Eventually one hundred lunar sample disks are expected to be made for use in both of the programmes. Each of the six samples in the disks weighs one-half gram and has been extensively analysed by university or government researchers. The results of that analysis are included with each of the disks. The total amount of lunar material expected to be used for the programme is about two-thirds of a pound. Apollo astronauts brought back 843.5 pounds of lunar material during the lunar explorations in the late 1960's and early 1970's.

SCIENCE EXPERIMENTS FOR LDEF

Four scientific experiments have been tentatively selected for NASA's Long Duration Exposure Facility (LDEF), scheduled as a major Space Shuttle payload in 1980. The experiments will study the hazards to man of ion particles in space, the chemistry of micrometeoroids, the interstellar wind and cosmic ray nuclei.

These experiments join 23 technology experiments chosen for LDEF earlier this year.

Nestled inside the Shuttle Orbiter's cargo bay during launch from NASA's Kennedy Space Center in Florida, LDEF will be placed in a circular Earth orbit of 435 km (270 miles) with an inclination to the equator of 28.5 deg.

The facility will remain in orbit from six to nine months while its experiments are exposed to the space environment. At the end of the mission, it will be retrieved by the Orbiter and returned to Earth.

Selected experiments and their principal investigators are:

- *Free Flyer Biostack Experiment.*
  Dr. Horst Bucker, Universitat Frankfurt am Main, West Germany.

Will investigate the biological effectiveness of the structured components of cosmic radiation during space flight, emphasising the effects of individual, very heavy ions. Information will be used to quantitatively assess the hazards of heavy ion particles to man in space, and establish radiation protection guidelines for man and biological experiments in future space flights. A six-month LDEF mission will yield about 360 per cent more total dose data than a typical Apollo mission.

- *Interstellar Gas Experiment.*
  Dr. Don L. Lind, NASA Johnson Space Center, Houston, Texas, and Dr. Johannes Geiss, University of Bern, Switzerland.

Will analyse the interstellar noble gas atoms that penetrate the heliosphere to the vicinity of Earth. The structure of the interstellar gas flux varies considerably at different points in Earth's orbit. By collecting particles at several locations, the experiment will achieve the first on-site detection of interstellar gas, and will study the dynamics of the interstellar wind as it flows through the heliosphere and interacts with the solar photon flux and the solar wind.

Because the dynamics of the interstellar wind depends on its density and velocity before entering the heliosphere, tne experiment will investigate these characteristics of the interstellar medium outside the region of the Solar System.

- *High Resolution Study of Ultra-Heavy Cosmic Ray Nuclei.*
  D. V. Domingo and Dr. K. P. Wenzel, European Space Agency, The Netherlands; Prof. C. O. Ceallaigh, Dr. D. O'Sullivan and Dr. A. Thompson, Dublin Institute for Advanced Studies, Ireland.

Will study charge and energy spectra of cosmic ray nuclei, and will search for super-heavy nuclei and heavy anti-nuclei. Information will help explain the physical processes of ultra-heavy nuclei production and acceleration at their source in interstellar space. Information on nucleosynthesis will also be obtained.

- *Chemistry of Micrometeoroids.*
  Dr. Fred Horz, NASA John Space Center, Houston, Texas.

Designed to obtain chemical analysis of a statistically significant number of micrometeoroids, and information about micrometeoroid density, shape and mass flux. If present hypotheses are correct, that most micrometeoroids are derived from comets, their chemical characterisation becomes of great significance. Comets are generally considered to be relatively unaltered objects that reflect some arrested condition of early Solar System condensation. Cometary solids appear to be rather primitive materials and, therefore, may offer rare insight into the formation of comets and the early Solar System.

POWER STATION IN SPACE

A far-seeing study that could ultimately lead to a huge power-station being built in space is being carried out by British Aerospace engineers who envisage an orbiting station capable of generating the same electricity output as five to ten power stations on Earth. The power station concept is part of a £59,000 six-months study contract awarded to BAe Dynamics Group at Bristol who are Europe's most experienced company in assembling space solar arrays.

Under the contract from the European Space Agency the BAe engineers are studying solar arrays that could provide extra power for the European Spacelab and space platforms as well as a space power station.

They are examining how solar arrays could be applied to future Spacelab missions and are identifying those areas where European technology in the subject could be most effective.

Spacelab, the manned space laboratory being developed by ESA, is due to be carried into space by the American Space Shuttle vehicle in 1981.

The laboratory will conduct space missions up to the year 2000, and these will require increasing power supplies. The additional power can be generated by converting the Sun's radiation into electrical energy using solar arrays.

A future development could be a "free-flying" power module capable of docking with the Shuttle vehicle, a satellite, or Spacelab itself and supplying it with 25 kilowatts of power.

Another concept is a space platform that would draw 50-500 kilowatts from its solar arrays.

In the field of space power plants, a pilot unit might be developed to go into a low Earth orbit or a geostationary orbit in a fixed position relative to the Earth and supply 1-2 megawatts.

From this could come a huge power station in geostationary orbit with a power output of 5-10 gigawatts (5,000-10,000 megawatts).

The power plants would be very large projects by any standards, and it is believed that Europe, through its already-demonstrated capabilities in space technology, would be able to make significant contributions.

BAe Dynamics Group is leading the study, and consultancy services are being provided by the Royal Aircraft Establishment.

Dynamics Group are presently providing, under contract to ESA, the 6 kW solar arrays for the NASA Space Telescope and are also developing a flexible fold-out solar array that will be deployed by a pneumatically operated telescopic mast. This latter array has a first potential application for a European TV Broadcast satellite.

ADVANCED LANDSAT

Two Multimission Modular Spacecraft (MMS) for Landsat D are to be built by Fairchild Space and Electronics Company of Germantown, Maryland, under fixed-price incentive contracts from NASA. The contractor's target cost is approximately $10.3 million for the basic requirements.

Hughes Aircraft Company of El Segundo, California, is a major sub-contractor responsible for development and testing of a propulsion module.

The MMS's will be basic spacecraft buses for the Landsat D flight spacecraft (to be placed in orbit in 1981 aboard a Delta rocket) and a backup. Other elements of this spacecraft are to be obtained under separate contracts. The new spacecraft is to be an advanced version of Landsats 1 and 2, now in orbit and surveying the Earth's surface to obtain data useful to agriculture, forestry, geology and other fields.

Under the contract, which will be managed by NASA's Goddard Space Flight Center, the company will integrate and test the two spacecraft buses. The work also includes (a) development and test of the propulsion module; (b) fabrication and test of a signal conditioning and control unit; (c) fabrication of a spacecraft structure; (d) thermal and electrical systems design and fabrication of a spacecraft harness; (e) acquisition of ground support systems and a simulator for spacecraft integration and test and for delivery to the spacecraft user, and (f) integration of these elements with three government-furnished subsystem modules (power, communication and data handling, and attitude control subsystems); (g) performance of an integrated system test; and (h) 24 man-months of instrument support.

The contract will also include options for the integration and test of up to four additional MMS's for future programmes that could be approved over the next five years.

WHEELS FOR 'APPLE'

The Indian Space Research Organisation (ISRO) has ordered four momentum wheel systems for satellite stabilisation from the German manufacturer TELDIX GmbH of Heidelberg under a contract worth DM 1.95 million. The order stems from the trouble-free operation, for more than three years in orbit, of a Teldix wheel installed in the Franco-German communication satellite Symphonie A at present broadcasting educational TV programmes for India. In addition, Teldix is manufacturing momentum wheels for the satellites OTS/Marots, Intelsat 5 and IRAS.

The ISRO contract covers two models for ground testing, a flight model and a spare. Each system consists of a DRALLRAD DR 22 (nominal speed 3,500 rpm, angular momentum 22 Nms) and a Wheel Drive Electronic Unit WDE 1.

The flight model will be used in the first Indian-built experimental communications satellite 'Apple' to be launched in May 1980 on the third test launch of the new European carrier "Ariane." 'Apple' means Ariane Passenger Pay-Load Experiment.

NASA's BOOK ON CETI

A 276-page summary of the findings of a blue-ribbon group of 16 US scientists on ways to detect possible radio signals from intelligent life in the Universe, called "The Search for Extraterrestrial Intelligence" (NASA SP-419), has been published by NASA's Scientific and Technical Information Office.

Edited by Professor Philip Morrison of the Massachusetts Institute of Technology and Drs. John Billingham and John Wolfe of NASA's Ames Research Center, Mountain View, California, the volume is based on the results of a series of SETI (an acronym for Search for Extraterrestrial Intelligence) workshops held during 1975 and 1976 on the West Coast.

It consists of three major sections: Consensus, Colloquies and Complementary Documents, and contains eight illustrations and numerous tables and figures. The book's Foreword is written by Dr. Theodore M. Hesburgh, C.S.C., President of the University of Notre Dame.

Much of the book is devoted to such complex subjects as preferred frequency bands, search strategies and scanning devices used on radio telescopes. The less technical "Consensus" section at the beginning of the book reviews in general terms the conclusions reached by the SETI group. These are:

- It is both timely and feasible to begin a serious search for extraterrestrial intelligence;
- A significant SETI programme with substantial potential secondary benefits can be undertaken with only modest resources;
- Large systems of great capability can be built if needed;
- SETI is intrinsincally an international endeavour in which the United States can take a lead.

It should be noted that the proposed NASA budget for Fiscal Year 1979 contains a request for $2 million for the start of a SETI programme by NASA's Jet Propulsion Laboratory.

The funds,if approved, are for an all-sky, all-frequency search for radio signals from intelligent extraterrestrial life, using existing antennae of the Deep Space Network at Goldstone, California, and some state-of-the-art hardware including a new very-wide-bandwidth supercooled preamplifier that will be developed specifically for the effort. The search would start in October 1978 and last for five years.

In their introduction to the book, the authors describe the SETI effort in these words:

> *"This is an exploration of a new kind, an exploration we think both as uncertain and as full of meaning as any that human beings have ever undertaken.*
>
> *"The search would be an expression of Man's natural exploratory drive. The time is at hand when we can begin it in earnest. How far and hard we will need to look before we find a signal, or before we become at last convinced that our nature is rare in the Universe, we cannot know."*

Copies of "The Search for Extraterrestrial Intelligence" can be obtained from the Superintendent of Documents, US Government Printing Office, Washington, D.C.20402. The stock number is 033-000-00696-0. The price is $4.50 plus postage.

BOOKING THE SHUTTLE

The National Aeronautics and Space Administration is taking reservations for Space Shuttle flights now for the years 1982 and 1983, according to Chester M. Lee, Manager of flight cargo schedules. Iran and West Germany have made partial payments for 1982-83 launches and Japan is considering a Spacelab flight in 1983, he said. Canada, India and the European Space Agency (ESA) have also reserved Shuttle flights. "We have all the cargo we can handle scheduled for 1980 and only a few spaces remaining for launch in 1981," Mr. Lee told government officials, engineers and space scientists attending an international meeting in Washington.

The Goddard Memorial Symposium of the international uses of the Space Shuttle and Spacelab drew 400 participants from the United Kingdom, Italy, Canada, Germany, France, India, Japan and the United States, writes USIS science correspondent Everly Driscoll.

A prime topic at the Symposium was the European Spacelab, being built by ESA to fly in the Shuttle's cargo bay. The multipurpose facility will be used for experiments in Earth observations, astronomy, physics, solar and atmospheric chemistry, biology and space manufacturing.

At the Shuttle Symposium, Dr. Arnold Frutkin, NASA Administrator for International Affairs, called the 400 million dollar investment by ESA in Spacelab a "remarkable contribution," and announced the completion of a critical design review of the Lab. Frutkin added that construction of the vital Canadian-built manipulator arm to be used to lift satellites out of the Shuttle and into orbit is "going very well." The manipulator will be controlled by engineers from inside the Shuttle Orbiter.

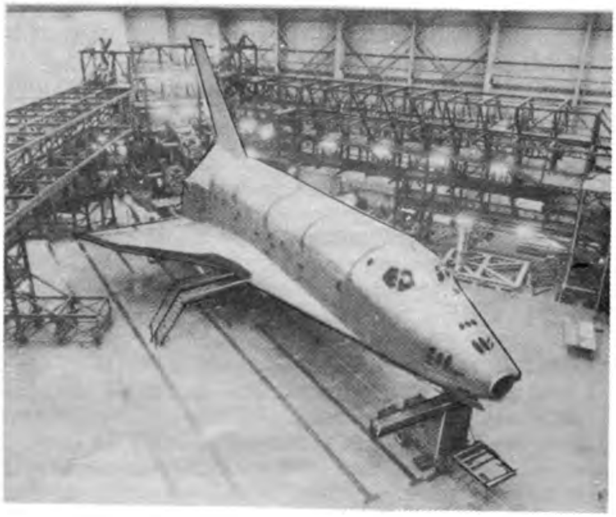
NASA and ESA will equally share the first Spacelab flight, scheduled now for December 1980. Selected as participants were 222 scientists. Of the 17 "principal investigators" chosen as coordinators of U.S. research, two were from outside the United States: T. Obayashi of the University of Tokyo and S. Biswas of the TATA Institute of Fundamental Research in India. Spacelab-1 will be an international venture with 14 countries represented – Belgium, Denmark, France, The Federal Republic of Germany, Italy, the Netherlands, Spain, Switzerland, the United Kingdom, Austria, India, Japan, Canada and the United States.

Spacelab-2, scheduled for April 1981, will carry experiments of 47 U.S. scientists and 12 United Kingdom scientists. Among the principal investigators are Allen Gabriel of Appleton Laboratory in Abingdon, Oxfordshire, and Peter Willmore of the University of Birmingham.

Spokesmen from France, India and Japan outlined their countries' future space plans including experiments aboard the Shuttle. Professor Pierre Morel of the University of Paris said that the Shuttle would be more economical and convenient for orbiting self-contained packages as well as sophisticated heavy experiments. "We recognise the great potential of the Shuttle for carrying heavy loads... such as the Space Telescope," he said, adding that "European astronomers are anxious to use the Telescope."

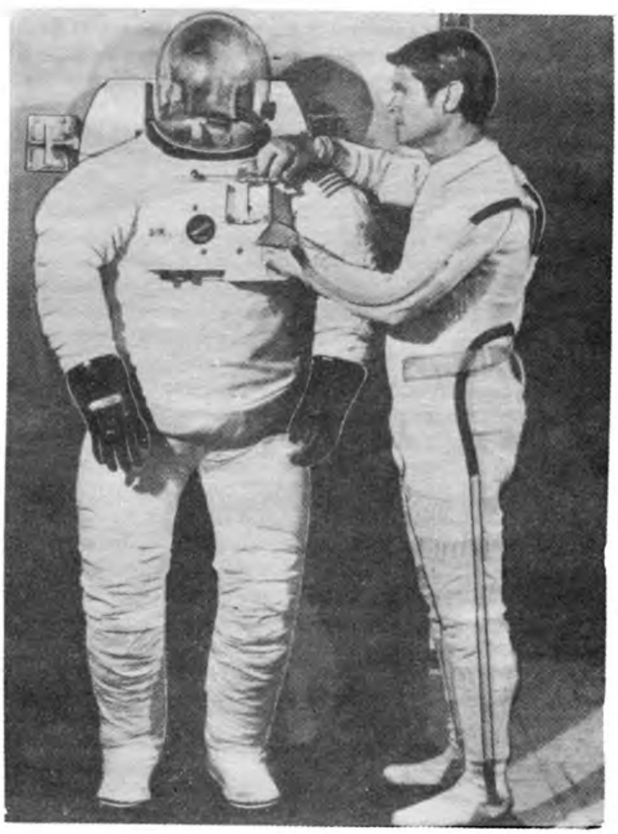
V. S. Rajan of the Indian Space Research Organisation (ISRO) noted that the Indian investment in space research over the next five years – 550 million dollars – will exceed its total investment of the last 15 years. Indian scientists have two experiments on the first Spacelab and a communications satellite, "INSAT," to be launched by the Shuttle.

Hiroshi Uda of Japan reviewed that country's space programme which includes launches by its own rockets as well as experimental communications and weather satellites launched by the United States. Study groups are investigating a wide range of future space experiments for Japan including astronomical and atmospheric observations, a space materials processing plant, biology laboratories and lunar and planetary exploration. Japan has an experiment on Spacelab-1.



'Bareskin' Space Shuttle Orbiter before being enclosed in a 430-ton reaction rig which will apply pressures of 300 lb/in^2 (21 kg/cm^2) *via* hydraulic jacks to validate the structural integrity. Some 2,700 load bearing pads had to be bonded to the outer surface of the Orbiter to carry applied loads. The 'Bareskin' structural test article later will undergo final assembly and be qualified for operational flight missions in 1981-82.

Space Division, Rockwell International



SHUTTLE SPACESUIT. Edgar H. Brisson, a Hamilton Standard engineer, models the Space Shuttle liquid cooling and vent garment that will be used to cool the astronaut when he is inside the Extravehicular Mobility Unit (EMU), pictured left.

National Aeronautics and Space Administration

Spacelab-1 will be carried by Shuttle Orbiter number 102, which is now being built in California. The first of its six test flights – manned launches into space as opposed to low-atmosphere manoeuvres completed last autumn with Orbiter 101 – is now scheduled for June 1979. Orbital tests will measure various flight dynamics of the Shuttle and test equipment for Earth observations, space physics and astronomy experiments as well as the Canadian manipulator arm. On the third test flight, pilots will attempt to rendezvous with the Skylab space station to boost it into higher orbit with a U.S. teleoperator propulsion system now being built. At present, Skylab is slowly being dragged Earthward, and will, if no action is taken, reenter the atmosphere between March and November of 1979. If corrective manoeuvres with Skylab now under way are successful. However, the Lab's descent to Earth will be delayed until the Shuttle can boost it higher. Following successful completion of six orbital test flights, the Shuttle will be operational. Among the first satellites to be placed into orbit will be a communications satellite for Canada.

SOLAR POLAR MISSION

Thirty scientific experiments have been tentatively selected by NASA and the European Space Agency (ESA) for the proposed Solar Polar Mission. The two spacecraft mission, planned for launch in 1983, is designed to observe the Sun for the first time from the unique perspective of its polar regions.

In doing this, the spacecraft will explore one of the remaining frontiers of the Solar System, namely the third dimension of space away from the plane of the orbits of the planets. All previous interplanetary space probes have flown in the orbits of the planets, which essentially intersect the Sun's equatorial regions.

NASA emphasised that the project has not yet been approved by Congress, but said that early selection of scientific participants and investigations allows for a prompt start when approval is received. NASA and ESA are providing one spacecraft each, and the combined scientific payload is divided between US and European investigators.

Spacecraft will be launched simultaneously by the Space Shuttle and then directed on a trajectory in the ecliptic plane (the plane which contains all of the planets) to Jupiter by an Inertial Upper Stage Booster.

The two spacecraft will swing around Jupiter and use the gravity of that giant planet to redirect their paths out of the ecliptic plane back toward the Sun in trajectories – one northbound and one southbound – that are essentially mirror images of each other. They will pass over the north and south solar poles, swing through perihelion (the distance closest to the Sun) in the ecliptic plane, pass respectively over the other solar poles and then fly back out to the vicinity of Jupiter's orbit. The period from launch until shortly after the second pair of polar passages is approximately five years.

The investigations are expected to return important new knowledge on the solar wind, cosmic rays and the three-dimensional structure and evolution of the Sun's corona (the outermost solar atmosphere). This information, in turn, will contribute to an understanding of the solar phenomena that shape and control our own planet's space environment.

Scientists now know that the high energy streams which are in the solar wind originate mainly in solar polar regions. In some way, these find their way to Earth, which is in the plane passing through the Sun's equator. These energetic streams may play an important role in weather changes. The Solar Polar Mission will shed light on this important question. The sources of these streams, the solar "coronal holes," exist primarily in solar polar regions, even during those times in the solar cycle when there is little solar activity.

The advantages of a dual spacecraft mission are significant. Sending spacecraft simultaneously over each of the opposite solar poles allows comparisons of the various solar and interplanetary phenomena that are affected by the differences in solar activity that typically occur between the northern and southern solar hemispheres. This duality of spacecraft greatly enhances the ability to understand how various solar activities affect the velocity, composition, density and magnetic field structure of the solar wind flow that impinges on the Earth's magnetosphere.

According to current plans, the northbound polar craft will spend about 110 days observing above a solar latitude of 60 degrees before swinging down over the southern half of the Sun. The southbound polar craft will move in an orbit that is a near-mirror image about the ecliptic plane of its companion.

In anticipation of a fiscal 1979 Congressional authorisation of the mission, NASA's Jet Propulsion Laboratory, which will manage the mission for NASA, is supporting studies of the US spacecraft, payload and mission design concepts. More than 150 American and European scientists will participate in the Solar Polar investigations.

SPACELAB BUILDING STARTS

The Spacelab project – a programme involving cooperation between the European Space Agency and NASA – has completed a very important milestone in its development phase. Following the Critical Design Review (CDR) of the project, which was considered highly satisfactory, ESA has decided to authorise manufacture of the Spacelab flight unit and to confirm the technical orientation already given in certain critical areas. The CDR was completed on 4 March by ESA, acting in association with the prime contractor, VFW-Fokker/ERNO, and with the participation of NASA. ESA and European industry were congratulated by NASA on the very positive result of the CDR.

The main objective of this review, the last one before the Flight Acceptance Review in connection with delivery of Spacelab, was firstly to verify the results obtained in the design phase and the manufacturing master drawings for the flight unit and compare both with the requirements defined in the agreements between ESA, NASA and European industry, and secondly to correct any divergencies and to give formal approval to the manufacturing of the flight unit.

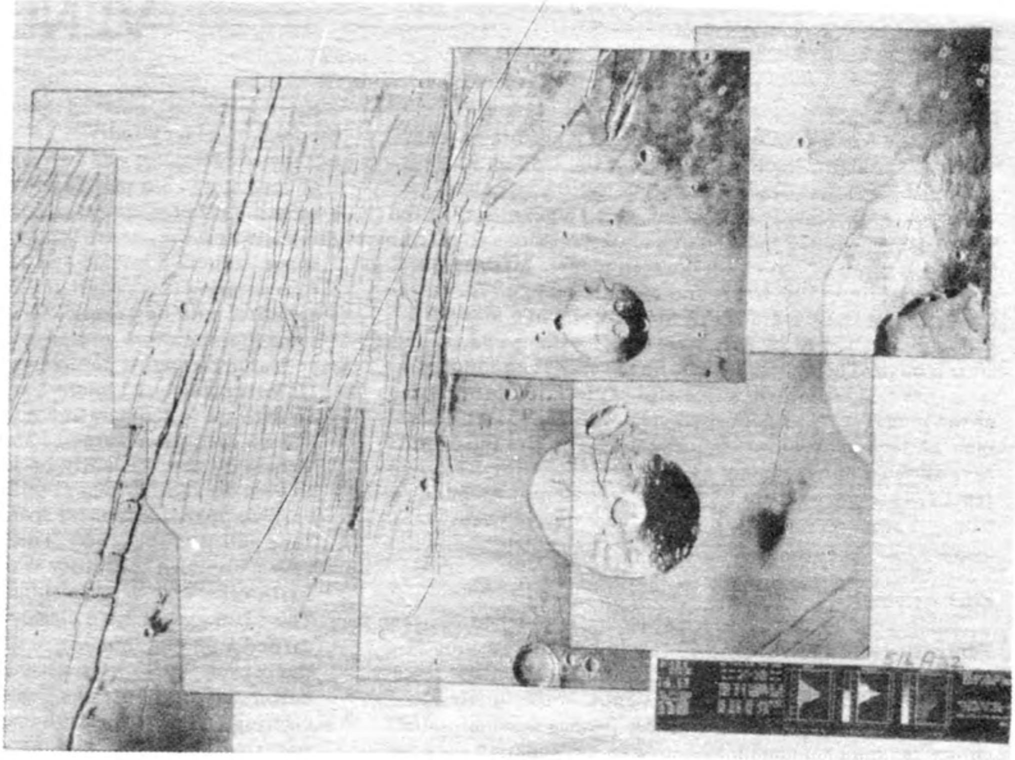
The CDR lasted two months, starting with the delivery in January of the drawings and detailed documentation and ending with a meeting of the ESA/ERNO Review Board held on the prime contractor's premises at Bremen, with the participation of NASA. Specialists in mechanics and structures, thermal control, electric and electronics, management and operations contributed towards this examination

The next milestone in the project will be the delivery of the engineering model to NASA, planned for mid-1979.

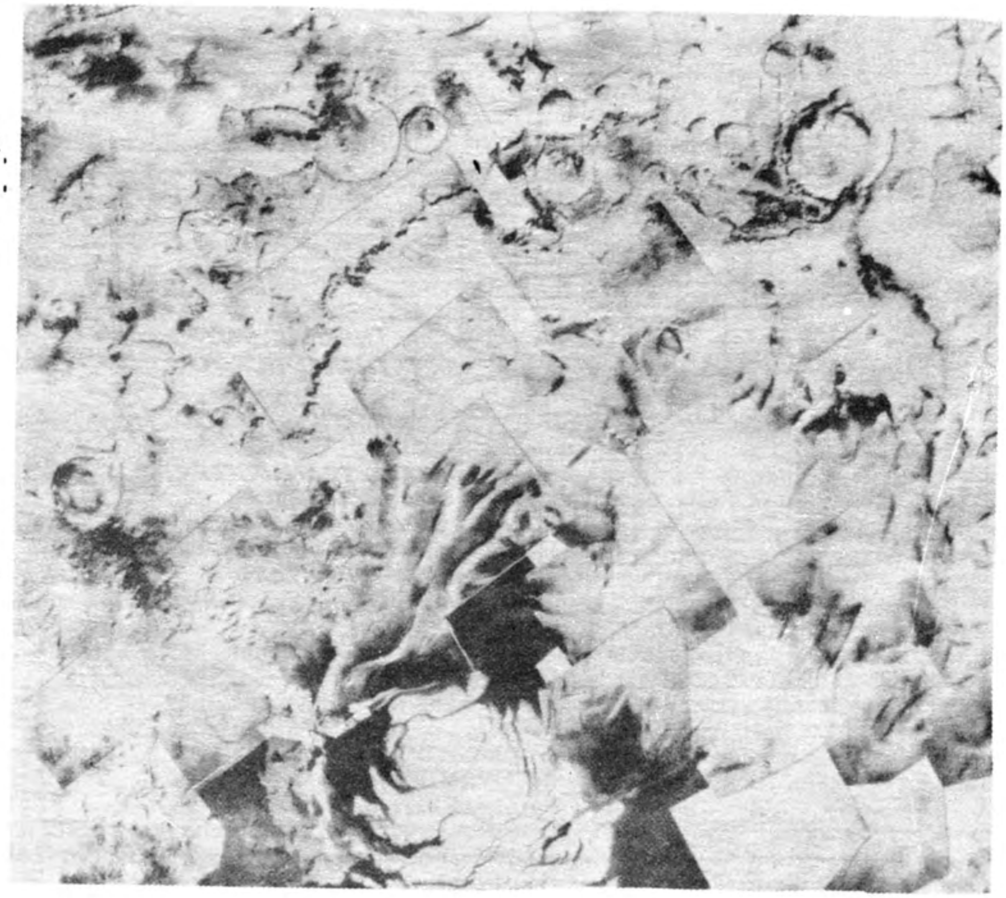
ESA will deliver the flight unit to NASA in two shipments, in autumn 1979 and early 1980 respectively, to satisfy the requirements of the first two Spacelab missions scheduled for December 1980 and April 1981.

EPSILON ERIDANI – A CLOSE BINARY?

CETI enthusiasts will be disappointed to learn that Epsilon Eridani – one of the two stars examined by Drake in Project Ozma – has recently been resolved as a very close binary. Unfortunately, the binary elements are such that the possibility of the system having a habitable planet must now be regarded as very remote.



MARTIAN RELIEF. Mosaic of photos from Viking Orbiter 1 shows the north-east margin of the Tharsis Ridge, the youngest volcanic region on Mars. An area of intense crustal faulting can be seen at left, and a cluster of volcanic mountains with prominent summit calderas is visible at right. The volcanos range from 65 km (40 miles) to 400 km (250 miles) across and are surprisingly varied in character. Volcanic crater chains, channels and individual lava flows can be seen on their flanks. Several large craters formed by meteorites that struck Mars are surrounded by ejecta that laps up onto the flanks of the volcanos. A prominent channel connects the summit of one volcano with an impact crater at its base. The curious relationship may indicate that one of the last eruptions of the volcano (named *Cersuniva Tholus*) may have been triggered by the fall of a giant meteorite. Viking took the pictures on 15 November 1977.



SOUTH POLAR CAP and environs from Viking Orbiter 2 during later summer in Mars' southern hemisphere. The south pole is just off the lower right edge of the bright residual polar cap; during winter all the area shown, 1,300 km (800 miles) across and much beyond, is covered by the seasonal cap that forms when carbon dioxide condenses from the atmosphere in the cold (-193 deg F) polar night. Unlike the residual north cap that is all water ice, the residual south cap may be either CO_2 or water ice, or a mixture of the two. A large impact basin, as large as *Argyre*, but much more degraded by erosion, is betrayed by the circular escarpment that can be traced over much of its circumference. To the right of the basin, the terrain is old and heavily cratered. Reduced cratering on the basin floor implies that its surface is younger than the surrounding region.

National Aeronautics and Space Administration

SOVIET ATMOSPHERIC AND SURFACE VENUS PROBES

By Nicholas L. Johnson*

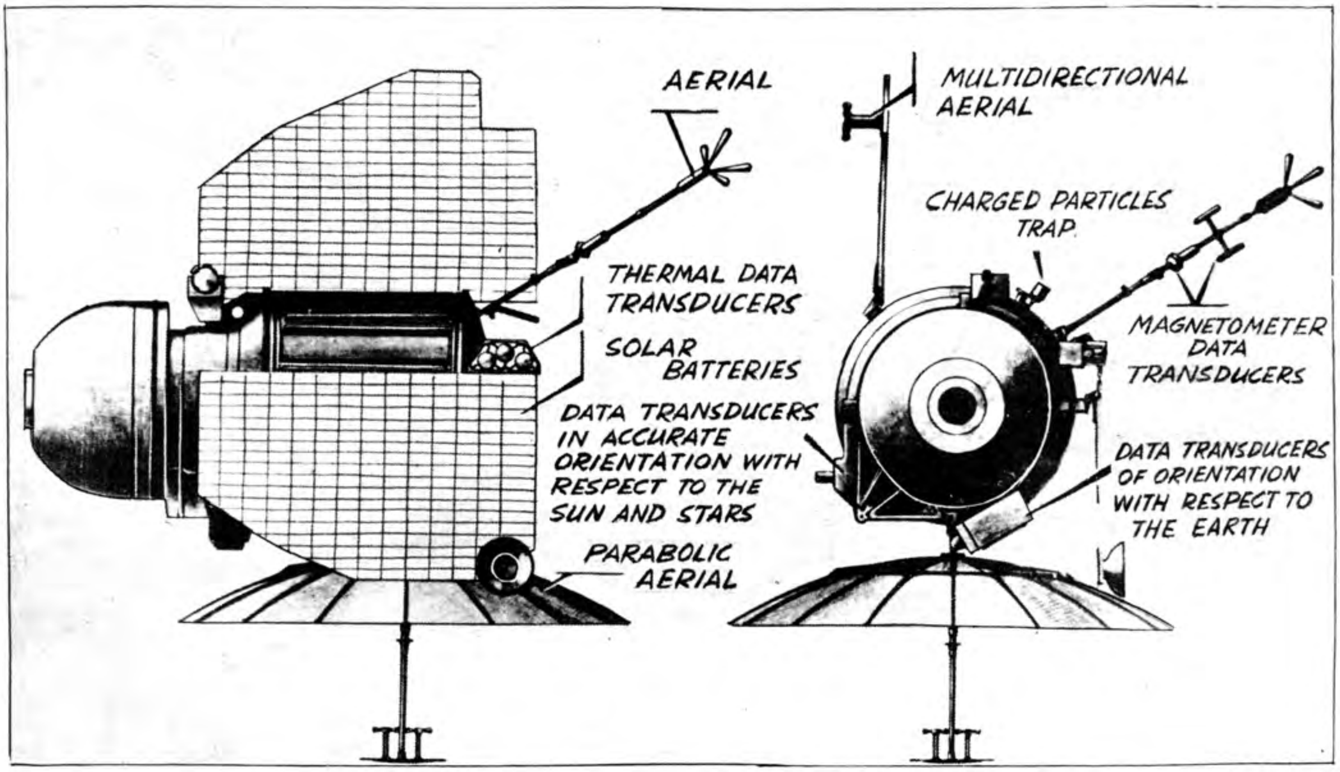
Introduction

With the forthcoming Pioneer Venus multi-probe scheduled for launch in August of this year, the United States is attempting her first exploratory penetration into the Venerian environment. During the past 16 years the United States has sent four spacecraft on fly-by missions to catch a fleeting glimpse of the cloud-covered planet: Mariner 1 and 2 in 1962, Mariner 5 in 1967, and Mariner 10 in 1974. Of the four, the last three were highly successful while Mariner 1 had to be destroyed by the range safety officer 293 seconds after launch. The Soviet Union, however, has conducted a relentless and ultimately successful exploration programme of the planet with Venera spacecraft. Since 1961 no fewer than 21 such probes were launched. In 17 years the Soviets have allowed only two launch windows (Oct-Nov 1973 and Jan 1977) to pass without an apparent attempt to launch a pair of Venera spacecraft. Both of these delays were necessitated by major spacecraft redesign efforts.

First Attempts

Table 1 indicates the seven spacecraft launched between February 1961 and April 1964 (excluding the Cosmos 21 test mission) for the purpose of conducting scientific research during flight in the proximity of Venus. Unfortunately, communications with none of these probes was maintained for longer than six weeks, resulting in no Venerian data return. In November 1965 Venera 2 and Venera 3 were launched with the missions of fly-by and atmospheric penetration, respectively. A third spacecraft, Cosmos 96, presumably identical to Venera 3, never left Earth orbit. The sister spacecraft weighed approximately 960 kg each and consisted of a cylindrical body, parabolic antenna of almost 2 metres diameter and two wing-like solar panels. The overall length was 3.6 metres with a maximum width across the solar panels of 4 metres [1]. Besides the scientific instruments installed on the carrier bus for investigations of interplanetary space, Venera 3 carried and was designed to eject shortly before entering the Venerian atmosphere a 900 mm diameter spherical landing capsule. This heavily insulated sphere contained temperature and pressure measurement devices to be activated during its parachute descent onto the planet. Unfortunately, as Venera 2 and Venera 3 approached Venus an increase in temperature disrupted radio communications and no data was returned [2]. It is assumed that the Venera 3 capsule silently became the first man-made object to land on another planet on 1 March, 1966 [3].

Two upgraded Venera spacecraft were launched on 12 June and 17 June, 1967. The first, Venera 4, was inserted into a Venerian trajectory while the second failed to leave Earth orbit and was subsequently designated Cosmos 167. The 1106 kg Venera 4 closely resembled Venera 3 and carried a 383 kg, one metre diameter landing capsule. Within the capsule were two resistance thermometers, an aneroid barometer, an ionization densitometer and 11 gas analyzer cartridges. The temperature sensors with a range of 0-400°C operated by resistance sensitive platinum wire in electrical bridge circuits. The ionization type densitometer measured the magnitude of a current between the inner surface of a β-active Strontium-90 coated cylinder and a central filament. The gas analysers, capable of detecting molecular nitrogen



Venera 1 launched from Tyuratam on 12 February 1961. Communications failed 15 days out from Earth when the craft had travelled 23 million km.

Novosti Press Agency

Venus Probe Summary

Type	Date Launched	Mission	Total Weight	Atmospheric Probe Weight	Results
Sputnik 7	4 Feb 61	Flyby	645 kg (?)	-	Failed to leave Earth orbit.
Venera 1	12 Feb 61	Flyby	643.5	-	Communications failed 27 Feb at distance of 23 million km.
Unannounced	25 Aug 62	Flyby	890 (?)	-	Failed to leave Earth orbit.
Unannounced	1 Sep 62	Flyby	890 (?)	-	Failed to leave Earth orbit.
Unannounced	12 Sep 62	Flyby	890 (?)	-	Failed to leave Earth orbit.
Cosmos 21	11 Nov 63	Test (?)	950 (?)	-	Failed to leave Earth orbit.
Cosmos 27	27 Mar 64	Flyby	950 (?)	-	Failed to leave Earth orbit.
Zond 1	2 Apr 64	Flyby	950	-	Communications failed about 14 May 64.
Venera 2	12 Nov 65	Flyby	963	-	Communications failed Feb 66 just before flyby.
Venera 3	16 Nov 65	Atmosphere Probe	960	?	Communications failed Feb 66 just before entry into atmosphere.
Cosmos 96	23 Nov 65	Atmosphere Probe	960 (?)	?	Failed to leave Earth orbit.
Venera 4	12 Jun 67	Atmosphere Probe	1106	383	First return of data from within atmosphere on 18 Oct; crushed at altitude of 27 km.
Cosmos 167	17 Jun 67	Atmosphere Probe (?)	1106 (?)	383 (?)	Failed to leave Earth orbit.
Venera 5	5 Jan 69	Atmosphere Probe	1130	405	Entered atmosphere on 16 May; returned data to an altitude of 24-26 km.
Venera 6	10 Jan 69	Atmosphere Probe	1130	405	Entered atmosphere on 17 May; returned data to an altitude of 10-12 km.
Venera 7	17 Aug 70	Lander	1180	500	First successful landing on 15 Dec; returned data for 23 minutes from surface.
Cosmos 359	22 Aug 70	Lander (?)	1180 (?)	500 (?)	Failed to leave Earth orbit.
Venera 8	27 Mar 72	Lander	1184	495	Successful landing on 22 Jul; returned data for 50 minutes from surface.
Cosmos 482	31 Mar 72	Lander (?)	1180 (?)	500 (?)	Failed to leave Earth orbit.
Venera 9	8 Jun 75	Lander/ Orbiter	4936	1560	First Venerian orbiter 22 Oct; Lander returned first picture and data for 53 minutes from surface same day.
Venera 10	14 Jun 75	Lander/ Orbiter	5033	1560	Second orbiter 25 Oct; Lander returned picture and data for 65 minutes from surface same day.

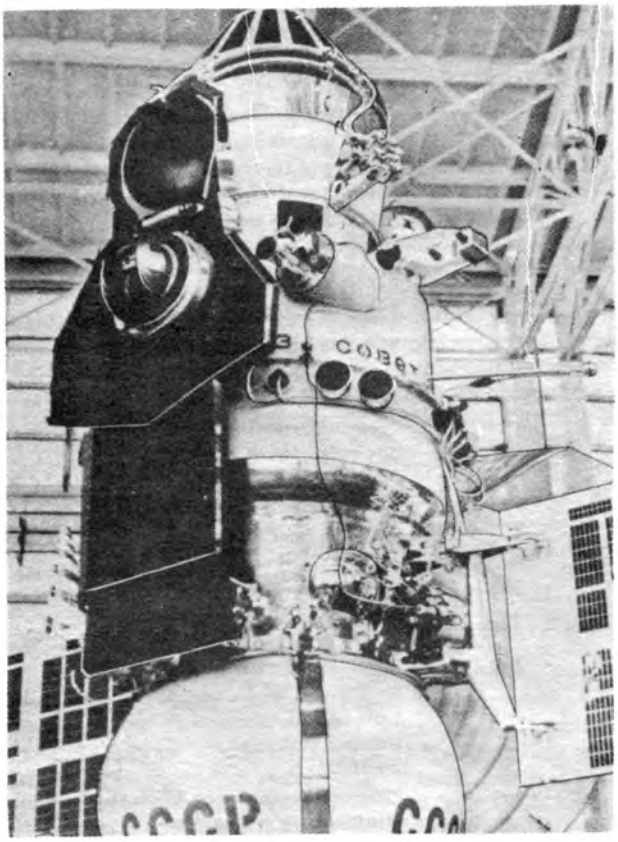
and oxygen, carbon dioxide, and water vapour, took two readings, the first immediately after opening of the parachutes and the second 347 seconds later [4, 5].

The Venera 4 descent capsule entered the top of the Venerian atmosphere on 18 October 1967 with a velocity of 10.7 km/s and was aerodynamically braked to 300 m/s at which point the parachute system was activated. When the velocity decreased to 10 m/s at a preset atmospheric pressure the instruments were turned on. After almost seven years and at least 13 spacecraft the first Soviet data was returned from Venus. Contrary to initial belief, subsequent analysis of the data from Venera 4 and Mariner 5, which passed by Venus a day later, revealed that Venera 4 had been crushed by the Venerian atmosphere at an altitude of 27 km and did not survive to the surface [6].

With the next launch window scarcely a year away there was not enough time to effect the major modifications required if a new landing capsule was to survive the entire descent to the surface of the planet. However, rather than skip the launch opportunity, two more spacecraft were readied with added insulation and smaller parachutes. Soviet scientists knew these new probes would not be able to function at the conditions existing near the surface, but more detailed information would be obtained from the upper atmosphere [7]. The 1138 kg Venera 5 and Venera 6 carried 405 kg descent capsules and encountered Venus on 16 May and 17 May, 1969, respectively. Venera 5 returned data down to an altitude of 24-26 km while Venera 6 may have survived to a slightly lower altitude. Each descent took a little more than 50 minutes on the night side of the planet. The data from Venera 5 and Venera 6 differed widely but indicated at least a minimum temperature and pressure of 400°C and 60 atmospheres. The atmospheric composition was almost entirely carbon dioxide (93-97%) with a trace of oxygen (less than 0.4%) [8, 9, 10].

Signals from the Surface

By August 1970 a more sophisticated and rugged Venera



Left, Venera 4 spacecraft replica with attached instrument capsule. *Above,* instrument capsule designed to soft-land by parachute.

Novosti/Flight International

7 spacecraft was ready for launch. Although still resembling previous Veneras, the craft weighed 1180 kg of which 500 kg comprised the landing capsule, capable of withstanding pressures up to 180 atmospheres and a temperature of 540° C for one to one and a half hours [11, 12]. Venera 7 was launched on 17 August while a sister craft, Cosmos 359, failed to leave Earth orbit five days later. After a 120 day flight the descent capsule was jettisoned from Venera 7 and began its searing descent, encountering temperatures up to 11,000°C during the aerodynamic braking. Prior to atmospheric entry the interior temperature of the capsule had been reduced to -8°C in an ingenious attempt to extend the useful life of the probe. The parachute system was deployed at an altitude of 60 km and within thirty-five minutes the capsule came to rest on the surface of Venus when, to the dismay of Soviet scientists, its signals appeared to cease. However, after extensive computer processing of the apparently unintelligible radio noise received after the landing, 23 minutes of useful data were extracted. The capsule had landed in such a way as to prevent a clear transmission to Earth, the reprocessed signals being at a strength of .01 of the power transmitted prior to landing [13].

After almost 10 years and 17 spacecraft the first scientific readings from the surface of Venus had been obtained though it was possible to decipher only temperature data. Together with what was known of the Venerian atmosphere from Veneras 4-6, a surface condition of 475 ± 20° C and 90 ± 15 atmospheres was calculated [14, 15]. Venus was truly an inhospitable planet!

When the next launch window occurred in March 1972 the Soviets' sent two more robots to explore the eternally veiled planet. The first, Venera 8, was injected into a Venerian trajectory on 27 March, but the second, Cosmos 482, apparently misfired on 31 March, and instead entered a highly elliptical Earth orbit. Although outwardly identical to Venera 7, the 495 kg descent capsule of Venera represented significant improvements. Since the surface environment had been roughly established by Venera 7, the materials used in the overdesign (in terms of maximum operating temperatures and pressures) of that previous probe could be exchanged for new scientific instruments. Among the new instruments carried were cadium sulphide photo-resistors for measuring the light flux through the atmosphere and on the surface; a device for detecting the amount of ammonia in the atmosphere; horizontal wind speed indicators for use at different altitudes during descent, and a gamma ray spectrometer to search for radioactive elements in the Venerian soil. Finally a second antenna was to be ejected on to the surface after landing to prevent the problem which plagued Venera 7 [16, 17].

On 22 July Venera 8 safely landed on the day side of the planet (the first probe to do so) and continued transmissions for 50 minutes from the surface. Interpretation of the data received indicated that the temperature and pressure at the Venera 8 landing site were 470 ± 8°C and 90 ± 1.5 atmospheres. Results of the gamma ray spectrometer indicated that the soil was probably of volcanic origin, resembling loose granite and possessing a density of 1.5 gm/cm^3. The amount of ammonia in the atmosphere measured at altitudes of 46 and 33 km was calculated to be between .1 and .01 per cent. Wind speeds ranged from 100 m/s above 48 km to 40-70 m/s between 42 and 48 km to less than 1 m/s below 10 km. The much awaited results on light flux measurements indicated that a sharp change in illumination occurred at an altitude of between 30 and 35 km. It was predicted from this data that the range of visibility at the surface where only 1% of the solar flux penetrates is approximately 1 km. However, during the operational time of Venera 8 the Sun

was only at an elevation of 5.5° ± 2.5° above the horizon. Greater illumination might well occur nearer the Venerian noon [18, 19, 20].

Second Generation Spacecraft

The October-November 1973 launch window passed without Soviet comment. This was the very first opportunity in which no Soviet attempts to send spacecraft to Venus were made since the first launchings in February 1961. Later it became clear that this brief respite signalled a major redesign and mission profile change for future Venera probes. The Proton launch vehicle which had replaced the A-2 booster in the Zond (1968), Luna (1969), and Mars (1971) programmes was now to be employed by future Venera spacecraft.

On 8 and 14 June 1975 Venera 9 and Venera 10, respectively, entered a brief Earth orbit and then departed Earth for a rendezvous with Venus in October. These second generation dual mission Venus probes were over four times heavier than any previous Venera spacecraft (approximately 5000 kg each) and closely resembled the second generation Mars explorers. Not only would each craft send a highly versatile 1560 kg lander to take measurements during its descent and on the surface, but also a 2300 kg satellite would be inserted into a Venerian orbit to become the first satellites of our closest planetary neighbour.

The two orbiters were to relay scientific data collected by the landers as well as to monitor Venus from altitudes ranging from 1300 to 114,000 km. The almost two metre high landers, which resembled a globe with a top hat, were designed to continue the experiments begun by the Venera 7 and Venera 8 landers with the important additional assignment of returning the first photographs of the surface. To perform the latter task a panoramic telephotometer with a 140-160 degree view of the surface would be aided by spotlights capable of 10,000 lux. Finally, a radiation densitometer, operating on the same principle as the one used on Luna 13 in 1966, was to be placed on the surface after landing [21, 22, 23].

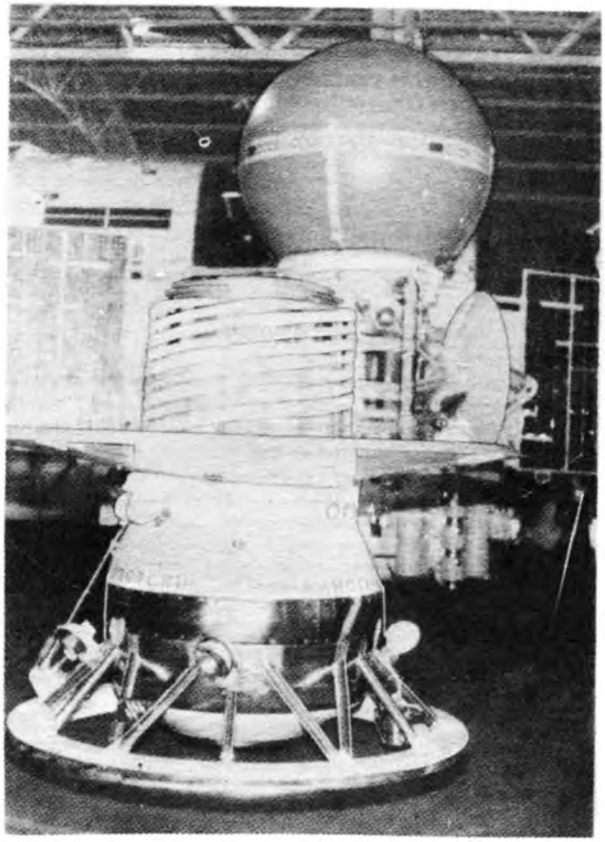
Two days before encounter the Venera 9 lander was separated from the orbiter and cooled internally to -10°C with an exterior temperature of -100°C. Upon entering the atmosphere the lander, encased in a 2.4 metre diameter sphere, began a descent sequence unique in lunar and planetary exploration. At an altitude of 64 km the upper hemisphere was ejected and a series of parachutes deployed, during which time the lower hemisphere was cast off. When the lander reached an altitude of 50 km the main parachutes were jettisoned, and with the aid of a circular air brake the spacecraft gently "fell" the remaining distance through the dense atmosphere. The entire descent lasted 75 minutes [24, 25].

The Venera 9 lander came to rest intact on the day side of the planet on 22 October 1975. Quickly, the first photograph was taken and relayed to Earth *via* the Venera 9 orbiter. Venera 10 followed a similar flight pattern, placing a satellite in orbit around Venus and a lander on the surface three days later. The 53 and 65 minute lifetimes of the Venera 9 and Venera 10 landers, respectively, greatly expanded our knowledge. The Venera 9 pictures showed sharp flat rocks while those seen in the Venera 10 photographs appeared smoother and weather beaten. The gamma ray spectrometer and radiation densitometer indicated the surface layer resembled basalt rather than the granite first suggested by the readings of Venera 8.

The Future

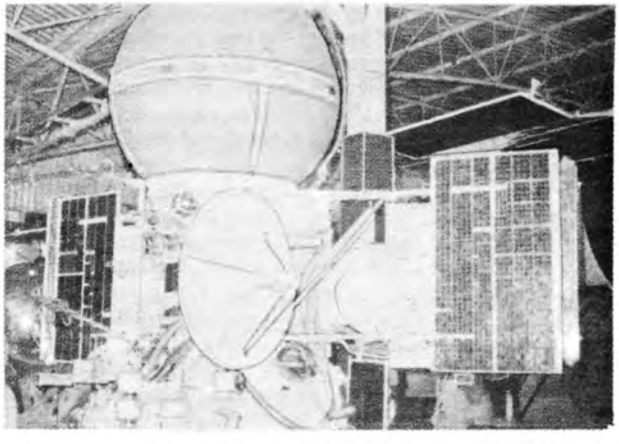
With the unqualified success of the Venera 9 and Venera 10 orbiters and landers, it came as only a slight surprise that the Soviets elected to skip the January 1977 launch window. Little more could be accomplished by Venera spacecraft without further redesign. However, in June 1977 the French announced that they will supply instruments to be carried on board two Venus probes scheduled for launch this year [26]. The exact nature of these probes has not yet been revealed.

Although no plans have been announced for the 1981 launch window, 1983 will witness a very ambitious French/Soviet undertaking. Shortly before entering a Venerian orbit, a Soviet spacecraft will release a French payload into the atmosphere. At an altitude of 55 km an 8 to 9 metre dia-



Replica of Venera 9/10 Lander on exhibition at the 32nd Paris Air Show.

Theo Pirard



The complete Venera 9/10 spacecraft showing the encapsuled Lander, extensible solar panels and communications antennae.

Theo Pirard

meter balloon will be inflated, carrying a 150 kg gondola beneath it. The balloon is expected to float in the atmosphere of Venus taking readings for up to 100 hours [27].

One wonders what significant improvements can be made to present Venera landers, limited as they are to operations on the order of one hour. Although some Soviet scientists have expressed desires to employ Lunokhod-type probes to planetary exploration, at this time a Venus rover does not seem practical, particularly with a lifetime as short as previous probes. Likewise the possibility of a sample return from the surface of Venus seems unlikely at this time.

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BIS DEVELOPMENT PROGRAMME

PROGRESS REPORT – II

THE SOCIETY'S NEW HEADQUARTERS

From earlier reports on the BIS Development Programme in *Spaceflight*, readers will know that, in October 1976, the Society purchased the freeholds of Nos. 27 and 29 South Lambeth Road, London, SW8. Although these properties were in a dilapidated condition through disuse, their basic structures were sound and offered considerable potential for development on a centrally located site.

Plans for adapting the two buildings to our needs were subsequently drawn up by the architect, Mr. George Hellewell, and involved joining the two buildings by a new structure to give a common facade and communicating interior. The scheme was well received by the authorities concerned and by July 1977 Planning permission had been granted by Lambeth Borough Council and the Greater London Council.

Detailed specifications were then submitted to three builders who tendered for the work at prices ranging from £157,000 to £225,000. Even the lowest of these offers was unacceptable as the cost involved greatly exceeded available resources. A detailed exercise was therefore undertaken, in conjunction with the architect, to scale down the specifications to a minimum while still providing adequate office space. The revised specifications were subsequently issued to other builders in order to obtain a competitive price. Three further tenders for the work were received which differed only marginally from each other in total cost. Offers for undertaking a major part of the work (a number of rooms on the first and second floors being closed off for later attention) amounted to just under £90,000. Even this figure substantially exceeded earlier projected estimates due to new fire and drainage regulations, together with the continuing high rate of inflation. Because of the ever-increasing trend in building costs, completion of the remaining first and second floor rooms is extremely urgent and should be undertaken, even at the expense of a loan to cover the further £20,000 that would be involved.

After consultations with the Society's bankers and solicitor, a fixed-price contract was placed by the Society in March 1978 with the builders, Knight & Evans Ltd. of Clapham, to undertake the entire revised specifications of work for a total sum approaching £110,000 with a completion date of 31 January 1979.

To date the BIS Development Appeal Fund totals £25,721 and is being actively applied to the development of the new BIS headquarters building. The need to promote the Appeal still more during the financially-crucial time ahead is clearly as urgent as ever before. Many generous donations have already been received from both members and friends of the Society.

In view of the continuing and enlarging scale of this support, the Society looks forward with confidence to embarking on a programme of new developments vital for the future of space exploration and utilization. All who wish to identify themselves with the work of the Society are urged to send a contribution NOW to the BIS Appeal Fund. This is the time when help really counts. Your donation, whether large or small, will be most gratefully received. Please give generously. Donations should be sent to: Mr. L. J. Carter, Executive Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ.

MISSIONS TO SALYUT 6

By Gordon R. Hooper

Soyuz 26

By 12.00 (all times expressed in GMT) on 29 November 1977, after two months in orbit, Salyut 6 had completed 968 revolutions. A trajectory correction took place on the previous day, following which the parameters of the station's orbit were 360 x 345 km (224 x 214 miles) x 91.4 min. x 51.6°. Telemetry indicated that the onboard systems were functioning normally.

On 10 December 1977, at 01.19, some 60 days after the return of the unsuccessful Soyuz 25, the Soviet Union launched Soyuz 26, callsign Taimyr, carrying a two man crew. The commander was Lt. Colonel Yuri Romanenko, and the flight-engineer Georgi Grechko. Romanenko was making his first flight, having previously served as back-up to Anatoly Filipchenko, the commander of the reserve ASTP Soyuz. Grechko was making his second flight, having previously flown as flight-engineer on Soyuz 17, and spending nearly 30 days onboard the Salyut 4 station.

The Soyuz 26 flight programme envisaged: the study of the physical processes and phenomena in outer space; the exploration of the Earth's surface and its atmosphere to obtain data on natural resources, etc.; medical and biological investigations; technical experiments and the testing of onboard systems and instruments; and testing and checking the docking assembly in the transfer compartment. Shatalov hinted that the mission would last only 3-4 weeks, but this later proved to be incorrect. He also said that "the working programme this time will be rather crowded."

Soyuz 26 was placed in an initial orbit of 245 x 205 km (152 x 127 miles) x 88.8 min. x 51.63° according to NORAD. At the time of launch, the Salyut 6 station was in a 355 x 339 km (220 x 211 miles) x 91.4 min. x 51.59° orbit The Soyuz completed 5 revolutions by 09.00, and then carried out a trajectory correction which placed the spacecraft in a 337 x 262 km (209 x 162 miles) x 90.27 min. orbit, according to NORAD. The official Soviet figures, however, were 329 x 267 km (204 x 166 miles) x 90.2 min x 51.6°.

All systems were reported to be functioning correctly, and the two cosmonauts felt well. While the craft was outside the Soviet radio zone, from 09.00 to 18.00, the men rested. The tracking of the spacecraft and the reception of the telemetry was carried out by the research ships *Cosmonaut Yuri Gagarin* and *Cosmonaut Vladimir Komarov*. The information was then beamed to a Molniya Comsat for re-transmission to Soviet MCC.

Docking with the Salyut took place at 03.02 on 11 December. According to Radio Moscow, Yuri Romanenko took over manual control when "only a few metres" separated the two craft. The switch from automatic to manual control usually takes place at the 100 m (109.3 yards) point. During the docking, Georgi Grechko kept an eye on the Soyuz instruments.

It was soon revealed that the crew had docked at a new second docking port, located at the aft of the Salyut station. The presence of this port was not announced beforehand. Following docking, the cosmonauts spent three hours in the Soyuz verifying that the docking interfaces had sealed correctly, and equalising the pressures in the two vehicles.

As is customary, the flight-engineer, Georgi Grechko was the first to enter the Salyut. "Come on in here and show yourself to the camera," he called to Romanenko. The two men were then shown embracing triumphantly in traditional Soviet "bearhugs;" they, and ground control, were obviously greatly relieved that the docking and transfer had been completed successfully.

Shatalov confirmed that ground control had followed the operation with greater anxiety than usual because of the failure of Soyuz 25. Sometimes, flights did not always go according to plan, he said. He was more nervous during the docking operation than when he himself carried out a similar docking in Soyuz 4 in 1969.

AT HOME IN SPACE. The record-breaking cosmonauts Yuri Romanenko and Georgi Grechko on the 'flight deck' of Salyut 6.

Novosti Press Agency

Soviet spokesmen went to great pains to stress the smoothness of the Soyuz 26 docking. Yeliseyev, the flight director, expressed satisfaction with the docking, which he said was carried out with exceptional accuracy, calmly and neatly at every stage. Shatalov described the docking as "very smooth, almost exemplary."

The Kettering Group scored yet again by being the first to announce the successful docking. Teachers' Geoff Perry (BIS Fellow) and Derek Slater were tracking the Soyuz at 04.20, and heard the Russian words for "pressure" and "power" which confirmed docking. They then rang Reuters and were told that there had been no word from Moscow, making them first with the news.

Konstantin Feoktistov, ex-cosmonaut and chief Salyut designer, when asked why *two* docking units were necessary, said that the second unit made for higher reliability. Should an accident occur, he said, such as a breakdown in the station's equipment, or a meteoroid strike, or should a fault occur in the Soyuz descent systems, it would mean jettisoning the Soyuz and sending up a replacement. But now, Salyut 6 could accommodate two spacecraft at a time, offering greater opportunities for experiments in outer space, as two crews could now work together, if required.

Feoktistov outlined the position of the new docking unit, and the design changes made to the Salyut. The second docking unit was located in the stern of the Salyut, in the equip-

ment compartment where previously only the propulsion unit was situated; this had to be substantially modified to make room for the docking port.

Although the two docking ports are identical and the automatic docking is the same at each end, the Salyut is manoeuvred so that the chosen docking port is facing the approaching ferry craft. Part of the Soyuz 26 crew's activities would be to inspect the forward docking unit and see if it was damaged in anyway.

Besides the second docking port, Salyut 6 carried other innovations, including thermo-regulating and attitude control systems which were in the experimental stages on earlier Salyuts. These were now said to be installed in their final form onboard Salyut 6. The water regeneration system was also in its final form. More TV cameras had been installed, there now being two B/W cameras and one colour, with three cameras mounted on the exterior of the station. These cameras were identical to those used onboard the ASTP Soyuz in July 1975.

More attention had also been paid by the designers to the comfort of the crew. A shower has been installed in the form of a small folding polythene cabin, into which hot water is sprayed under pressure. A pump is then used to extract the weightless water, which is fed through a special filter to separate the water and air for recirculation in the Salyut systems. The device appears to be similar to the Skylab shower, which US astronauts voted a waste of time, as it took 1-1½ hours to take a shower!

The onboard instruments were also said to have undergone great changes, making it possible to conduct extensive and more advanced astrophysical and bio-medical studies as well as the investigation of natural resources and tests of new technology.

On 12 December, the crew awoke at 04.00, and began the day with breakfast and a medical check-up. Both were in good condition, according to their own reports, and medical information transmitted to Earth. The cosmonauts then got down to activating the Salyut's onboard systems and scientific instrumentation. The life-support systems were maintaining a temperature of 21°C (70°F) and a pressure of 828 mm on the Mercury column, slightly above normal pressure. During the day, they also "mothballed" their Soyuz ferry.

On 13 December, the two cosmonauts were given a day of "active" rest, although the reactivation programme had not been completed. Doctors had decided that the crew should be in top form at the start of their complex experiments. According to the doctors, both men were adapting to weightlessness normally.

During their day of "rest," the crew checked out individual onboard systems and apparatus. By 11.00, Salyut 6 had completed 1,188 revolutions, 34 with the Soyuz 26 crew onboard. The parameters of the orbit were 363 x 337 km (226 x 209 miles) x 91. 4 min. x 51.6°. According to *Tass*, all systems were functioning normally.

Scientific Experiments

On 14 December, the two cosmonauts began their programme of scientific experiments, as well as continuing the reactiviation programme. In a colour TV broadcast, they showed the progress of an experiment in which tadpoles were hatched from spawn delivered by Soyuz 26.

The broadcast was the first from Salyut 6 using the colour TV, B/W having been used before. The crew gave a general tour of the space station, giving detailed descriptions of the onboard instruments. They also showed off their special suits, designed to combat the effects of weightlessness, and the teleprinter on which they received flight updates and world news, as prepared specially by Radio Moscow.

On 15 December, their programme included a check-up of the Salyut control systems in both manual and automatic regimes. They turned the station around to stabilise it in relation to the Earth. Further navigational tests were carried out with the Delta system. According to Vitaly Sevastyanov, who was taking part in the ground control of the flight, the crew were "performing splendidly," fully coping with their programme and doing even more than was required of them every day.

Radio Moscow announced that the Salyut crew were working to a new type of schedule. On previous flights, cosmonauts lived according to a system of staggered hours, so as to make full use of the periods when the spacecraft was passing over ground control stations. Since the Salyut passed over these stations at different times of the day or night, the crew's working hours had to be staggered. This involved sleeping at night one day, evening the next day, and morning the next, which the cosmonauts found very tiring.

Following medical advice, flight-controllers chose a new system for Salyut 6 crews. They worked according to Moscow time, with which they are accustomed. This was made possible by the increasing use of research ships such as the *Cosmonaut Yuri Gagarin*, and by using onboard data recorders to "dump" information when a ground station was in range.

Speaking about the flight, Feoktistov explained that the new docking port was situated in the rear of the station in the engine compartment. This had involved re-designing the whole compartment, and the two engine chambers are now on the side. There are also two small 10 kg thrust control engines.

On 16 December, the crew spent the day carrying out medical experiments. These included complex observations with the veloergometer bicycle bolted to the 'ceiling' of the station. The tests were designed to determine and forecast the cosmonauts' condition and the working capacity of their cardio-vascular systems. The aim of another experiment was to carry out an electro cardiographic examination of the cosmonauts.

The programme included an experiment for the study of blood circulation and the condition of individual groups of muscles which are used very little during a spaceflight. The medical examinations and crew reports showed that the period of adaptation to the conditions of weightlessness had practically ended. Both men were feeling well.

On 17 December, the crew continued the reactivation and checking of onboard systems and instruments. They had completed their first week in space.

Second Week in Space

On 18 December, Radio Moscow reported that the crew had completed the re-activation programme. The Salyut had been switched from automatic to manual control. Experts were saying that Romanenko and Grechko had been performing their assignments extremely well, and had adapted to the conditions of weightlessness.

On 19 December, the two men continued their work of preparing scientific instruments and technical documentation for their programme of scientific experiments. By 11.00, Salyut 6 had completed 1,283 Earth revolutions, including 129 with the cosmonauts onboard. The orbit was 365 x 335 km (227 x 208 miles) x 91.4 min. x 51.6°.

EVA Inspection

At 21.36 on 19 December, Georgi Grechko opened the hatch on the forward docking assembly and began the first Soviet EVA for nearly nine years. The last EVA was carried out by the Soyuz 4/5 flight in 1969. The objectives of the EVA were to inspect the outward elements of the Salyut, to check the faulty docking unit, and if necessary carry out repair work. Grechko inspected the exterior of the Salyut, and transmitted a running commentary together with TV

Cosmonauts Georgi Grechko, Oleg Makarov, Vladimir Dzhanibekov and Yuri Romanenko (left to right) pose for a picture on board the space complex Soyuz 26/Salyut 6/Soyuz 27.

Novosti Press Agency

pictures from a hand-held colour TV. His most detailed inspection was concerned with the primary docking system: "I attentively studied the butt end and the adjoining cowling. The butt end is brand new as though just taken off a machine tool," he radioed to Soviet MCC. "There are no scratches, traces or dents on it. All of the docking equipment – lamps, electric sockets, latches – all is in fine order. The receiving cone is also clean, without a single scratch."

During the course of the EVA, Romanenko stayed in the transfer compartment and handed tools and equipment to Grechko, who checked the docking unit's joints, sensors, guiding pins, fasteners and sealing surfaces. Special assembly, control and adjusting tools were used. "Everything is in perfect order. All the elements of the station, all the technology, antennae, batteries, instruments – everything," Grechko reported.

The two men wore new "semi-rigid" space suits, with EVA capability and increased mobility from the usual suits worn during the launch and descent phases. The new suit comes in a standard size and can be donned unaided in five minutes. It has a cuirass-like rigid torso, with a hatch in the back which swings shut and locks. It contains an autonomous life-support and communications system. Although the suit eliminates umbilicals, both men were tethered safely to the station.

The suit has a helmet and visor assembly similar to US EVA equipment. It consists of a clear helmet, which acts as part of the pressure vessel, covered with a visor assembly coated with a reflective substance to protect the cosmonaut from the Sun.

During the EVA, Grechko's suit was heated to 140°C (316°F) on the side facing the Sun, whilst the side in shadow dropped to minus 140°C. Inside the suit, however, a steady temperature was maintained.

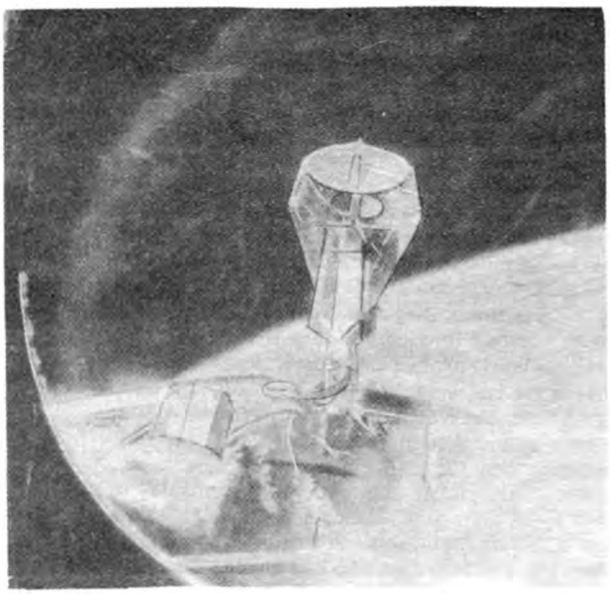
Looking around him during the EVA, Grechko said he could see the stars and the setting Moon. He could see tiny lights on Earth – probably cities. "Where are we now?" he asked MCC. He was told Salyut 6 was over the area of Lake Baikal in Siberia. Grechko beamed back colour pictures of the docking assembly, and then turned the camera on the Earth, letting viewers see large areas of the Soviet Union. They were also able to watch a sunrise, as seen from space.

Following the inspection of the docking assembly, Georgi Grechko reported that the unit was capable of receiving another manned Soyuz. Shatalov said that the reverification of the second docking port "will enable us to carry out the whole programme of further work (with) the the long-duration Salyut orbital station." Western observers speculated that a second manned Soyuz would be launched to link up with Salyut 6, although official Soviet sources were hinting that the two cosmonauts would conclude their programme by the end of the month. During the EVA, Grechko was said to be in good spirits, often cracking jokes. He later said of the spacewalk: "It's very difficult and complicated work, and at the same time a tremendous pleasure." During the exercise, Grechko "checked different methods of making an exit into outer space." Stable radio contact was maintained with MCC throughout the spacewalk.

Grechko returned to the transfer compartment and clambered through the hatch. Then he and Romanenko closed the hatch and raised the pressure in the compartment, before removing their spacesuits and returning to the main compartment of the Salyut. The entire operation had lasted 1 hour and 28 minutes, of which Grechko spent 20 minutes outside the Salyut.

According to Robert Christy, when Grechko emerged from the Salyut at 21.36, the space station was over 158°W 20°S, with the Cook Islands in the South Pacific directly below. The local time was 11.00, so the Sun was nearly overhead. When he returned to the Salyut, the station was over Santa Cruz, in the Argentine, at about 69°W, 50°S. The local time was about 17.00, still light. Salyut 6 entered the Earth's shadow about 12 minutes later.

Therefore, the entire 20 minute spacewalk took place in full sunlight over the southern hemisphere, and was completed some 35 minutes before Salyut 6 passed over Soviet territory. A medical check-up following the EVA showed



The view from Salyut 6. In the foreground is the antenna used during the docking approach sequence.

Novosti Press Agency

that both cosmonauts were in good health.

The two men had trained for the EVA using a Salyut mock-up in a new neutral buoyancy water tank facility at Zvezdnoy Gorodok. They also practiced in the spacesuits while flying zero-G trajectories in large aircraft, providing periods of up to 30 seconds weightlessness.

According to Vladimir Shatalov, EVA with Soviet cosmonauts working outside Salyut space-stations will be an inherent part of most, if not all, future Salyut missions. At a COSPAR meeting in Philadelphia in June 1976, the Soyuz 18/Salyut 4 crew revealed that previous Salyut crews had actually trained for EVA operations, but these had been cancelled owing to more pressing mission requirements.

The Soyuz 24 crew conducted a mysterious air-changing experiment onboard the Salyut 5 station, and with the benefit of hindsight, it is now easy to see that it was probably a test of the EVA procedures. The crew were said to have vented part of the station's atmosphere, while simultaneously releasing compressed air into the station from storage bottles. The purpose of the experiment was at the time, vague. According to the Soviets, "it was decided to test the system, which is important for prolonged expeditions. "On reflection however, it would seem likely that the Salyut 5 cosmonauts sealed off the transfer compartment and partly de-pressurised it, before finally restoring pressure.

On 21 December, Grechko and Romanenko conducted experiments on the exploration of the Earth's natural resources and the study of the environment for scientific and economic purposes. They carried out visual observations of the Earth's surface and studied glaciers, the snow cover over Soviet territory, and the surface of the oceans. Over Africa they reported seeing large forest fires.

On 22 December, the cosmonauts carried out a series of biological experiments. They examined the plants and micro-organisms they had brought from Earth with a view to planning air and water regeneration systems for future stations.

On 23 December, the men had another day of medical tests. A thorough medical check-up on each cosmonaut showed that their pulse and heart rates were the same as before lift-off.

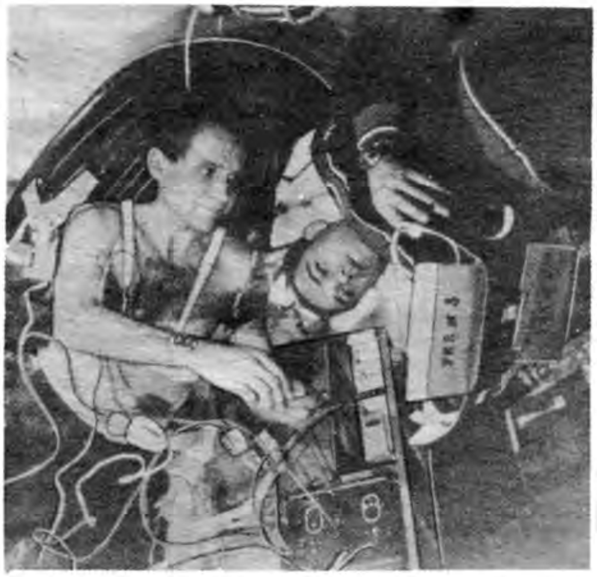
On 24 December, they carried out a programme of intensive physical exercise. They made use of their treadmill and velo-ergometer, as well as an area provided for jumping and other exercises.

On 25 December, the cosmonauts completed their 15th day in space. They tested the Delta automatic navigational system. Using a special lens, they determined the exact position of the space lab and its distance from the surface of the Earth at the time of observation. The data was fed into the onboard computer which calculates the orbital parameters. The station was reported to be orbiting the Earth at a speed of approximately 6 km/sec. (3.7 miles/sec.).

On the morning of 26 December, the cosmonauts studied the growth of water plants in conditions of weightlessness. In the afternoon, they were reported to be investigating the Earth's surface in conjunction with a ground team of environmental protection experts. Radio Moscow reported that in the last week, the crew had observed noctiluscent clouds over the North Pole, a brush fire near Sydney in Australia, and the enlarging oil slick off Southern Africa resulting from the collision of two supertankers.

On 27 December, the crew were given a day of rest, and they spent their time reading and playing chess. They had a few books onboard, some in English, as well as a magnetic chess set. The two men also had a video tape recorder allowing them to watch pre-recorded films. MCC reported that although it was officially a day of rest, the flow of information was as high as on any working day.

On 29 December, the Soyuz 26 engine was used to modify the Salyut orbit. Following the burn, the orbital parameters were 371 x 334 km (231 x 208 miles) x 91.3 min. x 51.6°



Cosmonauts Oleg Makarov and Vladimir Dzhanibekov prepare for a medical check-up aboard Salyut 6.

Radio Moscow reported that steps had been taken when designing Salyut 6 to reduce the level of noise generated by onboard instruments,etc. The hum of the motors, the breaking of various relays, the air filters and life support systems all contributed to a fairly high level of background noise. Cosmonauts had reported that even while they dozed, they were subconsciously listening to the background as confirmation that all systems were working normally.

Salyut designers, acting upon the advice of previous crews, had increased the sound insulation layers in Salyut 6 by 50%. Many switches were quietened substantially, and redesigning the engine compartment also reduced noise levels. In addition, the life-support system fans had been covered by panels on either side of the work compartments.

The success of these various measures was confirmed by Georgi Grechko, who had spent nearly 30 days onboard the Salyut 4 station. This new Salyut, he said, was a lot quieter. On 30 December, the two cosmonauts spent the day studying the Earth's surface and carrying out technical and biomedical experiments. They also studied the effects of weightlessness on living organisms.

During their flight, the two men were also carrying out important optical experiments. The Salyut has more than 20 portholes, and the degree of their transparency affected the accuracy of the scientific data. Outer space at altitudes of 200-300 km (124-186 miles) is not an absolute vacuum, and it had been found on previous flights that windows became covered with a thin layer of "space dust" and the effects of this layer on observations was being studied.

New Year's Eve

On 31 December, New Year's Eve, the men celebrated with a party and toasted each other with fruit juice. At midnight, Moscow time, they were over the Himalayas. However, as they were orbiting the Earth every 90 minutes, they actually had the opportunity to celebrate 15 times, as they crossed over time zones into 1978 and back again into 1977. According to *Novosti*, their first trip into 1978 came at 14.40 Moscow time, and they celebrated with the inhabit-

ants of the Far Eastern region of Chukotka. *Soviet News* and Radio Moscow however, claimed that the first occasion was when the station was over Kamchatka.

It will be remembered that in 1973, the Skylab 4 crew celebrated Christmas with a "tree" made from discarded food tins. The Salyut 6 crew went one better, and celebrated the New Year with a real fir tree, together with a special New Year's meal. In a Press Conference,Georgi Grechko described what they could see of the Earth, as they made their circuit every one and a half hours. "We often see the boundary of the seasons," he said. "Our cities in the northern hemisphere are snow clad, but their outline can be seen very clearly. And in the south, a hot summer has, in all evidence, set in; the snow has melted in the mountains, and rivers have dried." He also reported seeing a dust storm in Australia. "The Earth is equally beautiful from outer space, irrespective of whether it is winter or summer."

On 2 January, the cosmonauts had another day of medical tests, and studied their cardio-vascular systems and blood circulation. MCC reported that the two men were feeling fine. *Aviation Week and Space Technology* reported that the Soviets had said that "the aim of the work by the scientists and cosmonauts.... is the establishment of a permanently functioning scientific watch in orbit." If they succeeded in their aim of constantly manning the station it would represent a significant new milestone in manned space flight.

On 3 January, Romanenko conducted studies of the Earth while Grechko carried out astro-physical observations. They had completed a series of technical experiments, and now asked MCC to assign them more work, indicating that their workload was rather lighter than had been expected.

Medical specialists reported that the men had fully adapted to weightlessness, and were feeling fine. Their sight and hearing had both become more acute, a phenomenon encountered on earlier Salyut flights.

On 4 January, Radio Moscow carried details of one of the station's biological experiments. Onboard were two containers of tadpoles, one batch hatched onboard the Salyut, and one brought from Earth. Whereas the "terrestrial" tadpoles lost orientation and swam randomly, those hatched in space tended to swim in spirals.

The cosmonauts were also studying chlorella, which was being cultivated onboard the station. Eventually it is hoped to use the fast-growing algae both as a source of food and for oxygen regeneration on long space flights.

On 5 January, the cosmonauts made further observations of the Earth. They studied a strong ocean current skirting South America. Its boundaries were easy to detect because of the sharp contrasts in the colour of the water. Their observations showed that the present maps of the current were incorrect.

They also observed the melting of glaciers in the southern hemisphere. Some were said to be sky-blue in colour, while others were striped and "coloured like a chipmunk." These studies are related to forecasting the melting of glaciers, which affects the amount of water in the rivers originating in them. This in turn influences future harvests, and is particularly important to Soviet Central Asia with its large deserts and constant need for water.

On 6 January, the two cosmonauts saw, for the first time ever, Japan's highest mountain peak, Fujiyama. Usually, this volcano, 3.7 km (2.1 miles) high with a deep crater is shrouded in clouds. They also studied the stars and 'outer space phenomena.'

Their observations of noctiluscent clouds were carried out over the South Pole. Little is known about such clouds, although scientists believe that they form about 80 km (50 miles) above the Earth, and consist of particles of silicon and iron that collect in the form of micro-meteoroids or dust from volcanic eruptions. The clouds disappear after two or three days, probably due to the impact of the Sun's ultra-violet rays.

On 7 January, Georgi Grechko and Yuri Romanenko had another day of active rest, which they spent in exercising. MCC reported that Salyut 6 had completed 450 Earth revolutions with the crew onboard. During this time the station had been relying completely on the Delta automatic navigation system, referred to by AlexeiYeliseyev, the flight director, as "one of the most important engineering achievements of the flight." The crew also tested other new but unspecified navigation hardware.

On 8 January, they had a day of medical checks, including tests to determine the cosmonauts' response to different types of physical tests. Cardio-vascular tests were conducted using the bicycle-ergometer. The medical specialists concluded that both men were in good health, with normal blood pressure and pulse rates.

Soviet biologists were staging an experiment called "Medusa" on Salyut 6. In a set of containers placed outside the station, various mixtures of amino acids and other biological 'building blocks' were exposed to the full forces of solar and cosmic radiation. Inside the station, protected from the effects of this radiation, was a similar set of flasks. The biopolymers in the flasks were "micro-cultures which make up any living organism." Scientists hoped that "a comparison of these test samples will help establish what functional changes are caused in elementary living cultures by the entire spectrum of space radiation."

Analysis of the two sets of samples would be conducted on Earth, which meant that the containers mounted on the Salyut's exterior would have to be retrieved in some way, possibly by another EVÅ. The 'Medusa' experiment was said to have application "not only to the practical aspect of space travel, but also to the problems of the origin and transmission of life in the Universe."

On 9 January, *Aviation Week and Space Technology* reported that the level of work announced to be underway on Salyut 6 was substantially lower than that characteristic of past scientific Salyuts. The two cosmonauts were devoting more time to systems checkout and monitoring, although this could be because of the significant design changes incorporated in Salyut 6. It would seem, however, that the cosmonauts were carrying out an extremely thorough check in preparation for the second Soyuz docking to come.

They also spent significant time checking the Salyut's Delta autonomous navigation system, used to make and update onboard calculations of the spacecraft's precise orbital track and parameters. Delta requires no ground assistance to accomplish this, according to the Soviets.

Delta is also linked to the Salyut attitude control system, so various spacecraft attitudes can be programmed into the unit and then carried out automatically with cosmonaut assistance. The unit, tried experimentally on previous Salyuts, is now being used operationally, to free cosmonauts from devoting substantial time to controlling spacecraft attitude.

On 10 January 1978, as expected by some Western observers, a second two-man craft, Soyuz 27, was launched.

Acknowledgements

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[To be continued

SATURN IB

A retrospective look at major space achievements by David Baker

One by one the big expendable rockets which began a new era of human conquest in space are being eclipsed by the promise of the new in the shape of the re-usable Space Shuttle. The subject of our present nostalgia is Saturn IB which sent the first Apollo spacecraft on a ballistic trajectory through space on 26 February 1966. In 10 successful test flights NASA had validated the concept of clustered engines as reflected in the Saturn I launch vehicle, flown in the period October 1961 to July 1965 and by clustering eight H-I engines the space agency was able to provide a launch thrust of 6.67 million Newtons. In November 1962 NASA decided to put the S-IVB stage, then under development for the Saturn V, on top of an uprated Saturn I first stage and provide sufficient lift capability for early test flights of the Apollo spacecraft.

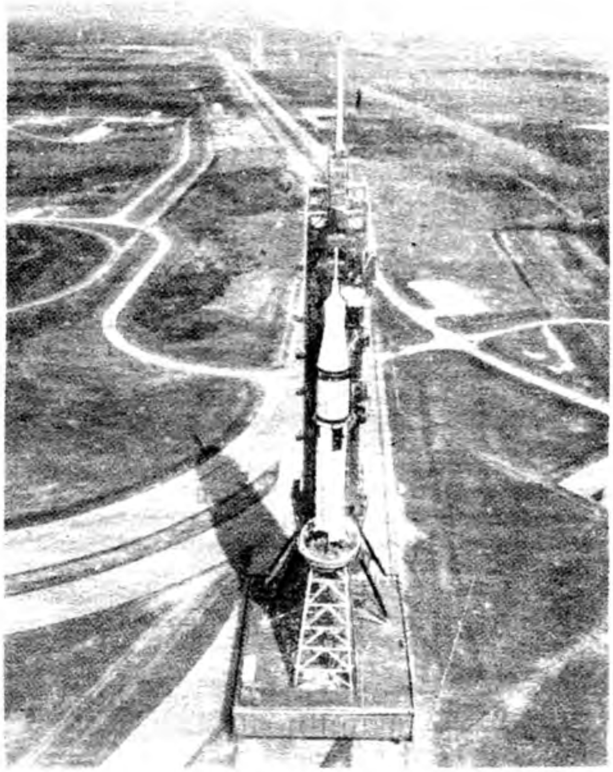
Called Saturn IB the launch vehicle would develop a thrust of 7.12 million Newtons and lift a maximum 16,000 kg to Earth orbit using the single 91,000 kg thrust S-IVB J-2 engine. In October 1963 NASA decided to cancel four manned Saturn I/Apollo flights and use the more powerful Saturn IB, proceeding toward an all up system test in 1966.

On 10 June 1964 the first uprated H-I engine was delivered to NASA and 13 months later the first S-IB stage was fired for 145 sec. Conveyed to the Kennedy Space Center aboard the barge *Promise* the first stage was delivered on 14 August 1965, passing through the new Cape Canaveral locks one week before formal dedication. The first flight S-IVB arrived at KSC aboard the barge *Steel Executive* on 19 September 1965 followed a month later by the spacecraft (009).

A successful countdown test was performed on 9 February 1966 and at Launch Complex 34 all looked ready for a lift-off on 22 February. Inclement weather delayed the flight on three attempts with the 25 February countdown carried to T-44 sec. before cancellation. Then, at 11:12:01 a.m. local time on 26 February, the 68.3 m tall Saturn IB lit up its eight first stage engines and headed out over the Atlantic. The four inboard engines shut down at 2 min. 21.4 sec. followed 5.5 sec. later by the four outboard engines. At 2 min. 29.3 sec. the single J-2 ignited, after separating from the first stage and adaptor, to produce a thrust of 89,200 kg for a further 7 min. 33.6 sec. At this point the 15,300 kg Apollo CSM separated from the inert S-IVB and coasted up to maximum altitude of 499 km.

Curving down toward the atmosphere the service module RCS engines were fired in a 30 sec. ullage burn before ignition of the SPS engine for a 184 sec. burn duration. Before entry the SPS was fired in a second, 10 sec., burn boosting the speed to some 8,380 m/sec., about 200 m/sec. less than planned due to a low oxidiser pressure on the first burn. Nevertheless this was 600 m/sec. faster than a normal Earth orbit re-entry and was sufficient to qualify the heat shield for the maximum heat rate expected on a manned flight. Temperatures reached 2,200°C during deceleration through the atmosphere and the parachutes were deployed at 3.6 km, lowering the command module to a splashdown at 11:49 EST, 8,690 km downrange, 56 km from the recovery ship *USS Boxer*.

The spacecraft was retrieved at 2:13 p.m. EST, 2 hours 24 minutes after splashdown, and taken to Norfolk, Virginia, where it arrived on 6 March. Five days later it arrived by road back at the North American Aviation (now Rockwell International) plant at Downey, California, having been flown to Long Beach from Norfolk. The mission, designated AS-201, had proved out the uprated H-I engines, flown an S-IVB stage for the first time and sent the first flight rated Apollo into space.



Roll-out of Saturn IB/Apollo on the Mobile Launcher from the Vehicle Assembly Building to Launch Complex 39B.

Bendix Corporation (Launch Support Division).

The Apollo payload was hardly representative of the design (fuel cells, radiators, crew equipment, cryogenic tanks and guidance & navigation equipment were all absent) but the mission had provided valuable data for confirming Saturn IB performance levels. A second Saturn IB was launched on 5 July 1966 to perform an S-IVB integrity check for qualification preceding application of the stage to Saturn V multi-burn requirements. The third flight, on 25 August 1966 repeated test objectives of the AS-201 mission and was the second Saturn IB ballistic flight. All seemed ready for the first manned Apollo flight and, with Gemini flights drawing to a close, a launch date of 22 February was set.

Before that could be achieved a disastrous launch pad fire had killed astronauts Grissom, White and Chaffee who were preparing to make a 14-day flight in Earth orbit, and the fourth Saturn IB (AS-204) was used instead to send the first Lunar Module, unmanned, on a systems test in January 1968. In October of that year AS-205 propelled Schirra, Eisele and Cunningham into orbit for a successful first flight of the modified Apollo CSM and in 1973 three Saturn IB vehicles boosted 9 astronauts to the Skylab space station. Finally, in July 1975, a Saturn IB sent the last Apollo spacecraft to rendezvous with Soyuz 19 and effectively closed the book on conventional manned space flight in the West.

In total NASA launched 9 Saturn IB rockets and all achieved success and, in a 9½ year period beginning in 1966, made a major contribution to the progress of manned flight.

SATELLITE DIGEST - 116

A listing of all known artificial satellites and spacecraft, complied by Robert D. Christy. Information sources include the Space Department of the Royal Aircraft Eastablishment at Farnborough, NASA, Novosti and both the popular and specialist press. For a more detailed summary, see Satellite Digest – 111, January, 1978.

Continued from May issue, page 193]

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle payload/launch origin
Cosmos 974 1978-01A	1978 Jan 6.66 12.60 days (R) 1978 Jan 19.26	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	178 175	334 325	62.81 62.81	89.61 89.49	Plesetsk A-2 USSR/USSR (1)
Intelsat 4A (F-3) 1978-02A	1978 Jan 7.01 indefinite	Cylinder + antennae 1511 fuelled 826 empty	2.8 long 2.4 dia	549 35768	35918 35806	21.82 0.3	640.44 1436.1	ETR Atlas-Centaur Hughes/NASA (2)
Soyuz 27 1978-03A	1978 Jan 10.52 64.95 days (R) 1978 Mar 16.47	Sphere + cone-cylinder + antennae 6570?	7.5 long 2.2 dia	190 241 330	237 304 350	51.71 51.58 51.60	88.71 89.90 91.28	Tyuratam A-2 USSR/USSR (3)
Cosmos 975 1978-04A	1978 Jan 10.56 60 years	Cylinder + 2 vanes 2500?	5 long? 1.5 dia?	634	653	81.22	97.62	Plesetsk A-1 USSR/USSR
Cosmos 976 1978-05A	1978 Jan 10.87 9000 years	Spheroid 40?	1.0 long? 0.8 dia?	1457	1465	74.03	115.14	Plesetsk C-1 USSR/USSR
Cosmos 977 1978-05B	1978 Jan 10.87 7000 years	Spheroid 40?	1.0 long? 0.8 dia?	1403	1465	74.03	114.54	Plesetsk C-1 USSR/USSR
Cosmos 978 1978-05C	1978 Jan 10.87 8000 years	Spheroid 40?	1.0 long? 0.8 dia?	1421	1465	74.03	114.74	Plesetsk C-1 USSR/USSR
Cosmos 979 1978-05D	1978 Jan 10.87 9000 years	Spheroid 40?	1.0 long? 0.8 dia?	1440	1465	74.03	114.95	Plesetsk C-1 USSR/USSR
Cosmos 980 1978-05E	1978 Jan 10.87 10 000 years	Spheroid 40?	1.0 long? 0.8 dia?	1465	1478	74.03	115.36	Plesetsk C-1 USSR/USSR
Cosmos 981 1978-05F	1978 Jan 10.87 10 000 years	Spheroid 40	1.0 long? 0.8 dia?	1465	1498	74.03	115.59	Plesetsk C-1 USSR/USSR
Cosmos 982 1978-05G	1978 Jan 10.87 10 000 years	Spheroid 40?	1.0 long? 0.8 dia?	1465	1518	74.03	115.81	Plesetsk C-1 USSR/USSR
Cosmos 983 1978-05H	1978 Jan 10.87 10 000 years	Spheroid 40?	1.0 long? 0.8 dia?	1465	1540	74.03	116.05	Plesetsk C-1 USSR/USSR
Cosmos 984 1978-06A	1978 Jan 13.64 12.7 days (R) 1978 Jan 26.3	Sphere + cylinder- cone? 5500?	5 long? 2.2 dia?	206	291	62.81	89.45	Plesetsk A-2 USSR/USSR
Cosmos 985 1978-07A	1978 Jan 17.14 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	945	1022	82.94	104.79	Plesetsk C-1 USSR/USSR (4)
Progress 1 1978-08A	1978 Jan 20.35 18.7 days 1978 Feb 8.1	Sphere + cone-cylinder + antennae? 7020	8.0 long 2.2 dia	173 250 329	256 334 348	51.61 51.66 51.60	88.73 90.29 91.25	Tyuratam A-2 USSR/USSR (5)
Molniya-3J 1978-09A	1978 Jan 24.29 12 years?	Cylinder-cone + 6 panels + 2 antennae 1500?	4.2 long? 1.6 dia?	646	40618	62.81	736.26	Plesetsk A-2-e USSR/USSR
Cosmos 986 1978-10A	1978 Jan 24.41 13.8 days (R) 1978 Feb 7.2	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	172 171	318 344	65.01 65.02	89.39 89.64	Tyuratam A-2 USSR/USSR (6)

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle Payload/launch origin
China 8 1978-11A	1978 Jan 25.21 12 days 1978 Feb 7	Cylinder? 3600?		161	479	57.03	90.90	Shuang Cheng Tze China/China (7)
IUE 1 1978-12A	1978 Jan 26.73 indefinite	Cylinder + octagonal cylinder + 2 wings	4.3 long 1.3 dia	173 25669	46081 45888	28.71 28.63	840.64 1435.7	ETR Delta NASA/NASA (8)
Cosmos 987 1978-13A	1978 Jan 31.62 13.6 days (R) 1978 Feb 14.2	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	175 173	321 351	62.80 62.80	89.44 89.72	Plesetsk A-2 USSR/USSR (9)

Supplementary notes:

(1) A redundant manoeuvring engine separated from 1978-01A during 1978 January 18, it is designated 1978-01D. Orbital data are at 1978 Jan 7.5 and 1978 Jan 14.2.

(2) Commercial communications satellite in geostationary orbit over the Indian Ocean, at 63° east longitude. Orbital data are at 1978 Jan 7.0 and 1978 Jan 15.0.

(3) Carried the second crew to visit the Salyut 6 orbiting laboratory, already linked to the Soyuz 26 ferry craft (1977-97A and 1977-113A). After five days aboard Salyut 6, the Soyuz 27 crew returned to Earth aboard Soyuz 26, thus releasing the aft docking unit for its originally intended use by the Progress 1 supply craft. The crew consisted of Lt. Col. Vladimir Dzanibekov – flight commander and Oleg Markarov, a civilian – flight engineer. Soyuz 26 undocked from Salyut 6 on 1978 Jan 16 and landed 1978 Jan 16.48, lifetime 37.43 days. Dzanibekov and Makarov flew for 5.96 days.

(4) Cosmos 985 may be a navigation satellite.

(5) Unmanned supplies ferry carrying fuel, materials and food to Yuri Romanenko and Georgi Grechko on board Salyut 6. Progress 1 docked with Salyut's aft docking unit at 1978 Jan 22.425. Romanenko and Grechko unloaded Progress over the next few days and on 1978 Feb 3, a quantity of fuel was transferred to Salyut. At 1978 Feb 6.25, now loaded with waste materials, the craft separated from Salyut, moved away and then performed a test of the backup rendezvous system at 1978 Feb 6.31. Progress was used to perform a small orbital adjustment on the triple spacecraft complex on 1978 Feb 5. After the completion of all experiments, Progress 1 was de-orbited over the Pacific Ocean. Although the design was based on the Soyuz craft, it did not carry a heat shield and thus it burned up on re-entry. Orbital data are at 1978 Jan 20.5, 1978 Jan 21.7 and 1978 Jan 22.4.

(6) Although Cosmos 986 changed orbit, the usual manoeuvring engine does not appear to have been separated before recovery. Orbital data are at 1978 Jan 25.1 and 1978 Jan 25.7.

(7) A section of China 8, weighing possibly 2400 kg was detached and recovered around 1978 Jan 30.

(8) International Ultra-Violet Explorer, carrying a 45 cm, f/16 cassegrain telescope and associated spectroscopic equipment. It is designed to operate at wavelengths between 1150 and 3200 Angstroms, in the ultra-violet region of the spectrum. These wavelengths are blocked out by the atmosphere, making them inaccessible to ground-based observers. IUE will be used by scientists from a number of countries. It is positioned near longitude 71° west, the orbit is inclined and eccentric in order to improve communications with ESA's European ground observatory near Madrid. Orbital data are at 1978 Jan 26.8 and 1978 Jan 28.3.

(9) A redundant manoeuvring engine separated from 1978-13A during 1978 Feb 12; it is designated 1978-13E. Orbital data are at 1978 Feb 1.5 and 1978 Feb 6.1.

Amendments and decays:

1972-75A, Molniya-2Ddecayed 1978 Jan 12, lifetime 1930 days.
1974-76A, Cosmos 687 decayed 1978 Feb 5, lifetime 1213 days.
1977-90A, Cosmos 954 decayed 1978 Feb 24.50, lifetime 127.92 days.
1977-115, a capsule separated from 1977-115A during 1977 Dec 23; it is designated 1977-115D.
1977-120A, Cosmos 969, add a second orbit of 166 x 306 km, 62.81 deg, 89.20 min. Orbital data are at 1977 Dec 21.5 and 1977 Dec 23.3. A redundant manoeuvring engine separated during 1978 Jan 2; it is designated 1977-120C.
1977-124, a capsule separated from 1977-124A during 1978 Jan 8; it is designated 1978-124D.

POSSIBILITIES FOR SKYLAB RE-USE

In the event NASA decides to reboost the orbiting Skylab space station to a higher altitude, what are the prospects for re-using the space station in some form? The large living quarters and crew accommodations aboard the Skylab would be a welcome adjunct to Space Shuttle and Spacelab missions involving extensive mission equipment and long mission durations. In addition, useful additional experiments might be conducted with Skylab instruments, in some cases in conjunction with complementary instruments planned for flight on Spacelab.

There is also the possibility for new experiments, missions or demonstrations made possible with the Orbiter and Spacelab docked with Skylab. This might include assembly and support of large space structures for communications, solar energy or other public service operations.

With these possibilities in mind, NASA's Marshall Space Flight Center has awarded parallel study contracts, each in the amount of $125,000 to Martin Marietta Corporation and McDonnell Douglas Astronautics Company. The two companies will conduct simultaneous but independent studies of the possibilities and benefits of Skylab re-use.

The nine-month studies will concentrate on missions, experiments and demonstrations that could most effectively use the Skylab facilities, and identification of benefits that could be derived from its use. Some of the areas to be examined are:

- Potential for using experiments or equipment already on board the Skylab and the opportunity to determine firsthand effects on materials and equipment of 10 or more years' residency in space.
- Possibility of providing crew quarters and other support provisions for Spacelab missions and experiments whose nature would benefit from long duration and an additional energy supply.
- Opportunities that the Skylab in itself, or in conjunction with other hardware elements, might offer for new missions or experiments. For example, the relatively large facility (comparable to a three-bedroom home) might provide a convenient work platform for fabrication and construction of large space structures or help turn these structures into useful demonstration or operational systems.

BOOK REVIEWS

The Solar Planets
By V. A. Firsoff, David and Charles, 1977, pp. 184, £5.50.

This book was written after the arrival of Vikings 1 and 2 on the surface of Mars and looks at the major planets of the Solar System mainly in the light of recent exploration by interplanetary probes, and, in the case of the Moon, manned and unmanned spacecraft. The sixteen plates illustrate the Moon and planets as they were never seen from Earth, and demonstrate how great a revolution has taken place in our knowledge of the planets during the last decade.

About ninety pages are devoted to Mercury, Venus, Earth, Moon and Mars, while some 20 pages are directly related to the outer planets. Mr. Firsoff's books are usually controversial and he often supports ideas that are not much in favour at the time. For this reason this book should not be read as a summary of generally accepted opinion but as a stimulating resume of the author's views. New techniques may have destroyed many earlier beliefs about the nature of the planets but we are far from understanding the origin or even the nature of some of the features that have been revealed. As is usually the case with major developments in science, more questions have been raised than answered.

Mr. Firsoff takes what is probably a minority view over the origin of the lunar features and believes that, while some craters are of impact origin, most are due directly or indirectly to vulcanism. He believes that water was once present on the Moon in large quantities and that some features are due to running water while others are due to the collapse of ice domes and melting permafrost. Whether this view can be sustained in the light of the complete absence of water in most (but not all) Apollo rock samples is questionable. However, it is now generally accepted that there has been water on Mars in sufficient quantities to shape the surface, ice caps exist now as do volcanoes, some of which may still be active, and the rocks seen in the Venera 9 and 10 photographs appear to be volcanic, a view supported by recent Earth-based radar observations of the topography of Venus.

This book will certainly start the reader thinking and, having read it, study other reports and books. The conclusion that – even at the present rate of exploration – it will be a long time before the origin and nature of the major planetary features is understood is inescapable.

M. J. HENDRIE

Supernovae
Ed. D. N. Schramm, D. Reidel Publishing Company, 1977, pp. x+192.

This volume in the admirable *Astrophysics and Space Science Library* series records the proceedings of the special IAU session on supernovae held in Grenoble in September 1976. Some 16 wide-ranging papers are presented from most of the leading researchers in a field which ranges from the origin of cosmic rays to the synthesis of the bulk of the heavy elements observed in nature and the formation of neutron stars and possibly even black holes.

A paper by Lasher, Karp and Chan dealing with the early Type 1 supernova light curve and the effect of hydrogen abundance is followed by a note by Branch on a particular use of supernovae, *viz:* to determine a value for the Hubble Constant and the advantages in this approach. Culhane presents an account of X-rays from supernovae remnants. Such objects were, as Culhane reminds us, the first class of X-ray emitting objects to be positively identified and were, in fact, the only sources of X-ray emission to be predicted as such before the commencement of observational X-ray astronomy in 1962 using sounding rockets. However, it was the later introduction of satellite-borne instruments which led to the more spectacular results.

Chevalier discusses the Crab Nebula, the most studies of all supernovae remnants, and which, as is well known, is associated with a pulsar (and an optical pulsar at that). Chevalier attempts to reconcile the properties of this object with those of Type II supernovae taking into account available information on the present nebula, the pulsar and the original supernova event in 1054, whilst Weiler and Wilson present 'evidence for a class of supernova remnants resembling the Crab Nebula' (at least in their radio properties), the Crab previously having been considered unique. Chechetkin *et al.* summarise Russian work on carbon detonation supernovae and neutrino transport supernovae, and (no doubt to retain the balance) a paper by Epstein summarises U.S. work also on mechanisms for supernovae explosions. This latter paper deals with gravitational collapse of massive stars and discusses the problems relating to neutrino transport mechanisms.

Tamman's presentation of his comprehensive analysis of statistics on supernovae is described by Schramm as 'one of the highlights of the Special Session, and examines the rate of supernovae occurances in various types of galaxies. On the evolution of supernovae remnants there are three observational papers, whilst Colgate and Petschek attempt to show that supernovae might explain quasar phenomena. In particular, it is shown how shocks emerging from supernovae and interacting with surrounding material could possibly explain important features of quasar observations.

Other papers include Truran's contribution on supernova nucleosynthesis and altogether this volume of an excellent, long running series will provide a most useful and concise summary of the 'complete phenomena of supernovae' (at least up until mid-1976). However, one major criticism must lie in the abominable and amateurish typographical presentation; in fact, the contributions are merely photographically reproduced typed manuscripts with many and varied type faces. It is to be regretted that such a retrograde step has been taken with such a 'quality' series as this.

S. G. SYKES

Dynamical and Chemical Coupling Between the Neutral and Ionized Atmosphere
Eds. B. Grandal and J. A. Holtet, D. Reidel Publishing Company, 1977, pp. 392. $36.00 U.S.

This specialist book is intended for scientists and graduate students involved in meteorology, atmospheric physics, ionospheric physics, aeronomy, sun-weather relationships, atmospheric composition, transport processes, atmospheric waves and auroral phenomena. It represents a formidable collection of review papers over wide ranging topics concerned with the neutral and ionized atmosphere.

The broad guidelines were the study of the mid- and high-latitude atmosphere within the height range of 30-160 km. The book, which follows the programme of the proceedings held in Norway, is divided into four main sections with an additional small section on special topics at the end.

The four main sections are:

1. The Neutral Atmosphere.
2. The Ionosphere.

3. The Coupling between the Neutral and Ionized Atmosphere.
4. Atmospheric Emissions and Auroral Phenomena.

The Neutral Atmosphere section consists of seven papers covering temperature, turbulence, atmospheric waves and assorted neutral gas constituent profiles covering the stratospheric and mesospheric regions. Possible effects caused by solar cycle modulation are discussed. A particularly good paper was written by K. Labitzke on stratospheric and mesospheric midwinter warmings. This describes the effect of high altitude warming of the atmosphere caused by energy transfer upwards from the troposphere.

A very good collection of seven papers on the Ionosphere deal with the full range of electron and ion processes, including effects of electron precipitation and electron collisions in the energy transfer process.

Particularly good papers include one written by F. Arnold and D. Kranowsky concerning ion composition and electron- and ion- processes in the altitude range 20-100 km. The concept of the formation of cluster ions is considered in some detail. Another is the paper by J. B. Reagan which covers ionization processes below 100 km altitude. All the principal sources of ionization are discussed, including the significant role of electron precipitation and the associated bremsstrahlung in the ionization and modification of the neutral atmosphere.

The third section includes seven papers which discuss variations in the ionization of the stratosphere and mesosphere which may effect weather conditions in the troposphere. Changes in ionization may be caused by solar flare or supernova conditions or variability in the emission of solar extreme ultraviolet and ultraviolet wavelengths. This change in ionization alters the concentration of minor gas constituents, such as nitrogen dioxide, which, in turn, affects the chemistry of the upper troposphere. The results of these changes may be a decrease in overall global temperatures, accompanied by changes in the Earth's albedo.

The volume concludes with five papers studying solar - terrestrial interactions in high latitude regions.

Two very good papers may be mentioned. Data from magnetometer experiments on the Triad satellite, launched into a nearly circular polar orbit of 800 km altitude, in November 1972, is presented by T. A. Potemra. Results seem to confirm the existence of large scale geomagnetic field-aligned currents, of the order of 10^6 Ampere, which flow into and away from the lower ionosphere. A paper by W. K. Peterson *et al* examines results from the photoelectron spectrometer experiment in the Atmosphere Explorer satellites. High resolution energy spectra for electrons of 1-500 eV at altitudes down to 140 km are available over the entire Earth's surface. Important areas of interaction can therefore be studied in greater detail.

A short selection on special topics discusses, in three papers, some future aspects related to ionospheric research. These are, the possible advantages of an Antarctic area location for an experimental base, the anticipation of Spacelab and improvements in spectral analysis techniques.

Like so many others presenting a collection of scientific papers, this book tends to exhibit a certain lack of cohesion. The reader becomes involved in a good paper and would like more but he must move on into a new area. However, each paper provides a wealth of reference material for those wishing to pursue a given topic.

This is a high quality reference book for those researching or otherwise interested in ionospheric and associated phenomena.

JOHN S. BURY

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CONTENTS

COVER

THE SPACE SHUTTLE is currently undergoing a series of ground vibration tests in a tall test fixture at NASA's Marshall Space Flight Center, Huntsville, Alabama (see page 262). *Top left and bottom,* 'Enterprise' is hoisted into the dynamic test stand on 21 April. *Right,* inside the stand, the spaceplane is lowered into position alongside its External Tank. The Tank and Shuttle Orbiter were mated and then 'soft mounted' inside the test stand using a system of air bags and cables to suspend the vehicles from a large overhead truss. First Shuttle ground vibration tests involved these two Shuttle components in a simulated flight condition. Subsequently, tests will be made in conjunction with the Solid Rocket Boosters.

National Aeronautics and Space Administration

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 20 NO. 7 JULY 1978 *Published 25 June 1978*

With great regret we record the death on 8 May 1978 of Harry E. Ross, one of the Society's most distinguished Fellows. Harry was one of the 'elder statesmen' of Astronautics, having contributed in 1937-39 to the BIS study for a manned spacecraft to land on the Moon. Soon after World War 2, he produced a detailed design for a lunar spacesuit, and in conjunction with the late R. A. Smith made engineering studies of a man-carrying rocket and a space station powered by solar energy. His vision extended to space colonies in which human values could be worked out anew. Of the Apollo Moon landings, he wrote: "at last the slate is clean."

MILESTONES

April

10 Report from Peking suggests that China has given space technology high priority in modernisation programme. Fang Wi, deputy prime minister for science and technology, says plans over the next eight years include a major space research centre, scientific and applications satellites, manned space flight and an orbital laboratory.

12 Launch of ESA's second Orbital Test Satellite (originally scheduled for launch 20 April) is put off until 4 May because of anomalous signals registered during pre-launch checks which necessitated changing a coaxial cable. (OTS-1 was lost last September when the American Delta 3914 launch vehicle exploded 54 seconds after leaving the launch pad at Cape Canaveral).

12 Soviets reveal that film of Earth exposed in the multi-zonal camera MKF-6M during the early part of the 96-day mission by Salyut 6 cosmonauts was returned to Earth by Soyuz 27 cosmonauts. After being processed, photos were taken back to space station by Soyuz 28 cosmonauts to help crew identify surface features under examination.

13 Back-up receiver of Voyager 2 switches on automatically as planned seven days after a short circuit blew fuses in the power line of primary receiver. Full communications are restored and a set of computer programs transmitted to spacecraft to ensure that science data will be returned during Jupiter flyby even in the event of subsequent failure of No. 2 receiver.

15 Vladimir Shatalov, head of cosmonaut training, says next international flight to Salyut 6 space station will be manned by a Soviet and a Polish cosmonaut. Flight will be made after a Soviet crew has reoccupied Salyut. Both training and flight preparation are virtually complete. There will be another supply mission by an unmanned cargo ship of the Progress type. Dates and durations of missions will be decided in the light of space conditions and fuller understanding of previous missions. Later this year an East German will be taken up to Salyut 6.

17 USAF awards $264.9 million contract to Boeing Aerospace Company of Seattle for full-scale development and initial production of the multi-stage, solid-propellant Inertial Upper Stage (IUS) designed to transfer satellites or space probes from low-Earth orbits to high energy or interplanetary trajectories. Of nine initial vehicles, four will be built for Department of Defense and five for NASA. Contract extends to 1 October 1981. IUS is compatible with both the Titan 34-D and re-usable Space Shuttle.

19 NASA reports that six American and two British scientists are candidates in the competition for two payload specialists' seats aboard the second flight of Spacelab to be flown in the Space Shuttle Orbiter in 1981. Finalists are: Loren W. Acton, 42; Lockheed Palo Alto Research Laboratory; John David F. Bartoe, 33, Naval Research Laboratory Washington, D. C.; John W. Harvey, 37, Kitt Peak National Observatory, Tucson, Arizona; Bruce E. Patchett, 30, Appletoll Laboratory,

[Continued overleaf

Astrophysics Research Division (Culham Laboratory), Abingdon, Oxon, U.K.; N. Paul Patterson, 38, Ball Brothers Research Corporation, Boulder, Colorado; Dianne K. Prinz, 39, Naval Research Laboratory, Washington, D. C.; George W. Simon, 43, Sacramento Peak Observatory (Air Force Geophysics Laboratory), Sunspot, New Mexico; and Keith T. Strong, 26, Mullard Space Science Laboratory, Dorking, U.K. Spacelab 2 will feature no manned module. Most of its experiments will be exposed to space on pallets in the Orbiter payload bay. Because of this, the Payload Specialists will operate the instruments from the Orbiter crew cabin. Four of the candidates will undergo extensive training following a final selection this summer. Of the four payload specialists trained, two will go into space, while the other two will perform support and advisory roles in the Payload Operations Control Center at NASA's Johnson Space Center in Houston.

24 Report from Warsaw says Polish and East German cosmonauts will continue micro-gravity materials processing experiments begun by Soviet and Czech cosmonauts aboard Salyut 6. Flight of 8 to 9 days duration will test different furnace apparatus to determine optimum systems.

26 Peoples' Republic of China reported to have signed agreement with West Germany to use Franco-German Symphonie 1 satellite, in geo-stationary orbit above Indian Ocean, to test and qualify Chinese-built ground stations in readiness for national comsat project planned for launch 1981-82.

28 U.S. Congressional sub-committee cuts $1,400,000 from NASA SETI (Search for Extra-Terrestrial Intelligence) programme, leaving $600,000 for FY 1979, "not enough even to start design work on a radio antenna."

30 Search for debris from nuclear-powered Cosmos 954 which disintegrated over north-western Canada on 24 January ends this week. Costs to date estimated at about $5 million Canadian dollars (£2,430,000).

30 Soviet scientists visiting Johnson Space Center confirm intention to obtain lunar samples from hidden side of Moon and place unmanned satellite into lunar polar orbit by early 1980's.

30 Largest solar flare for 10 years causes auroral effects and magnetic storms on Earth.

30 NASA postpones launch of Seasat-A at Vandenberg Air Force Base, California, to allow certain sensing equipment in the satellite to be changed. Launch is delayed until 30-31 May at the earliest. Seasat – based on an Agena rocket stage with extensible solar panels – is designed to enter a circular, near polar orbit at 800 km (497 miles). Satellite has five sets of experiments: radar altimeter; synthetic aperture imaging radar; scanning multi-channel microwave radiometer; microwave wind scatterometer, and visible/infra-red scanning radiometer. Will supply sea and weather conditions to improve ship routing, detect sea ice, chart shoals of fish (e.g. tuna and salmon) which follow seaborne nutrients moving to warmer waters.

May

2 Ground equipment associated with launch of European OTS-B is struck by lightning.

3 NASA postpones launch of OTS-B "at least 48 hours."

5 Technicians discover malfunction in OTS-B Delta rocket's first stage guidance box. After box is replaced a problem is found in the Inertial Measuring Unit (IMU) in rocket's second stage. Launch re-scheduled to 11 May.

11 NASA launches ESA Orbital Test Satellite (OTS 2) by Delta 3914 from Eastern Test Range, Cape Canaveral, Florida. OTS 2 was built by the European MESH consortium led by British Aerospace Dynamics Group's Stevenage Space Division. It carries a communications payload developed by AEG/Telefunken and Selenia. Satellite will be stationed in geo-stationary orbit 10 deg east over Gabon to enable experimental communications between countries of Western Europe, the Middle East, North Africa, the Azores, the Canary Islands, Madeira and Iceland. OTS 2 will be succeeded in 1981 by ECS (European Communications Satellite), a fully operational communications system capable of handling a significant proportion of future European telephone, telex and TV traffic.

13 Onboard apogee boost motor of Orbital Test Satellite (OTS 2) fired at 1310 hrs BST places satellite into near-synchronous orbit. Gas jets now will manoeuvre the satellite into its final position 10 deg east, over Gabon. *(This was achieved within one week, about three weeks earlier than allowed, when OTS 2 was declared ready for its first experimental transmissions. Satellite was launched from Cape Canaveral at 2359 hrs BST on 11 May. Ed.).*

18 British Interplanetary Society publishes Final Report of Daedalus star probe which runs to 192 pages, price £6.00 ($12.00). *(Orders and remittances to the Executive Secretary, British Interplanetary Society).*

U.S. RECONNAISSANCE SATELLITE PROGRAMMES

By Anthony Kenden

Introduction

For the last decade and a half the United States and the Soviet Union have been keeping watch on each other from space, using reconnaissance satellites to observe ballistic missile sites, weapons testing and deployment, military exercises, factory and shipyard construction, and a whole host of other "interesting" activities. This may seem like an aggressive and unwarranted intrusion into each other's security, but it is in fact a vital part of the balance of power which has maintained peace and restrained the arms race. The great importance of these reconnaissance satellites and their findings has been implicitly acknowledged by the inclusion in the SALT agreements of clauses specifically prohibiting interference with the other party's "national technical means of verification."

A considerable proportion of the satellites launched by both the United States and the Soviet Union have been related to reconnaissance, but they have received very little publicity. Indeed, it is probably the only topic in the whole space exploration field that accounts of Soviet activities are more readily available to the public than accounts of American ones; for a description of Soviet reconnaissance programmes the reader is referred to [1]. It is the aim of this article to provide an overview of American programmes involved in satellite reconnaissance, and to give an indication of their capabilities.

The Beginnings of Surveillance

At the end of the Second World War several hundred German workers who had been involved with the V-2 project were taken to work in the Soviet Union. By 1952 most of them had been allowed to return to Germany, and they brought back with them stories of Soviet developments in the missile field, stories that sounded ominous to Western military experts. Their real significance was brought home by the explosion of the first Soviet hydrogen bomb on 12 August 1953, only nine months after America's first [2]. To an America steadily cutting back its military strength, the prospect of the Russians having a nuclear armed intercontinental missile was not a pleasant one. It thus became of the greatest importance for the US to find out just how far Russian developments had progressed, and this meant surveillance of Soviet missile tests. A radar station was set up at Samsun in Turkey, which gave ample coverage of the tests conducted from Kapustin Yar, 1,550 km to the northeast [3]. However, it soon became clear that these missiles, with their impacts 1,500 km away in the Kyzyl Kum Desert, were only IRBM's and that the ICBM tests were to be carried out from another launch site, much deeper inside Soviet territory, and out of range of foreign radars. To monitor the ICBM tests the U-2 aircraft was developed, and flights over the Soviet Union began in June 1956. By the spring of 1957 the new cosmodrome at Tyuratam had been discovered, and by the middle of the year a U-2 flying out of Peshawar in Pakistan had brought back photographs of it [4, 5]. As the need for information grew, the flights became longer and longer, until it was decided to make one way trips across the Soviet Union from Peshawar to Bodö in northern Norway. During the first of these, the great disadvantage of the U-2 came to light: on 1 May 1960 Gary Powers was shot down by a ground-to-air missile near Sverdlovsk, and in the uproar that followed all further U-2 flights over the Soviet Union were cancelled.

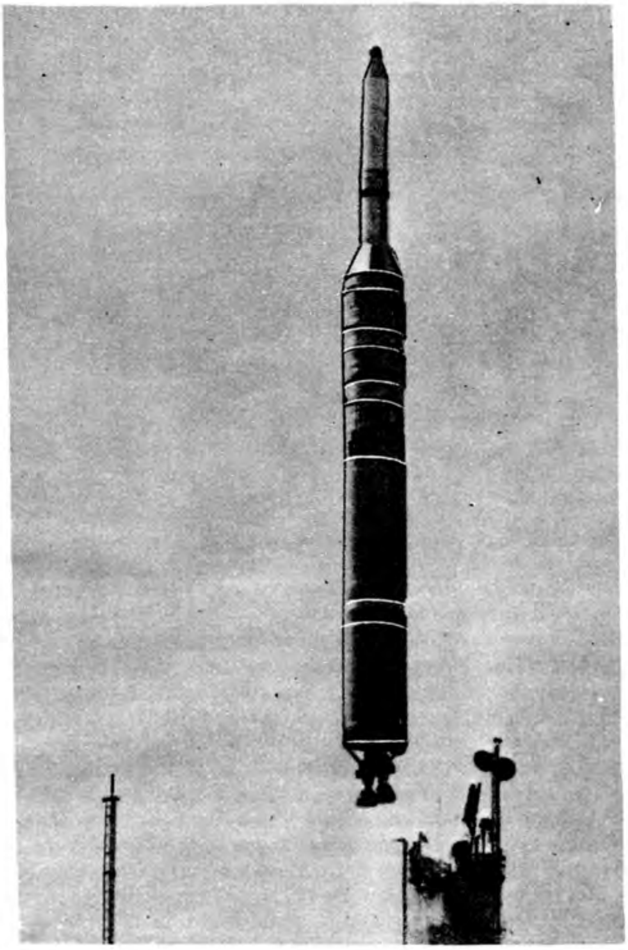


Fig. 1. A Titan 3B blasts off from Vandenberg Air Force Base, California. Rockets of this type have been used extensively to launch close-orbit reconnaissance missions (see Table 3).

United States Air Force

As far as the public was concerned, this seemed to be the end of American surveillance of the Soviet Union, but in fact it was just the beginning. For some time the USAF had been working on a new approach – observation from unmanned satellites. Studies of these started soon after World War II, and as far back as 2 May 1946 Project RAND (soon to become the RAND Corporation) produced a report discussing the technical aspects of a satellite vehicle. In April 1951 they produced a report entitled *Utility of a Satellite Vehicle for Reconnaissance* [6]. On 16 March 1955, four months before the United States was to announce plans to launch a scientific satellite during International Geophysical Year (IGY), the USAF, under the sponsorship of the CIA, issued a formal request for proposals for a "Strategic Satellite System," to be designated WS-117L. On 30 June 1956 the contract was awarded to Lockheed, and the satellite vehicle they developed, the Agena, is still in service today [7].

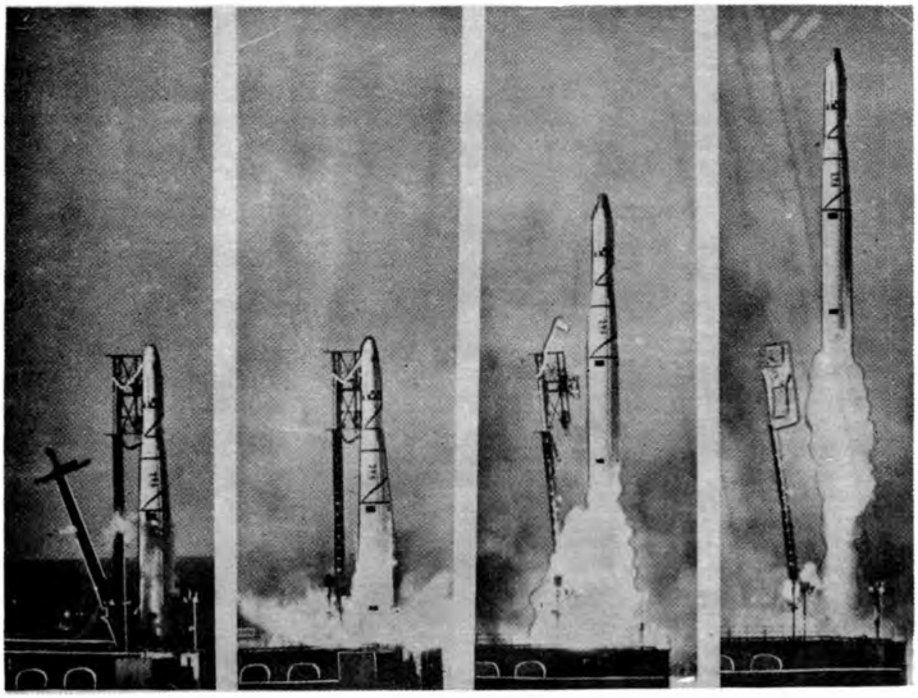


Fig. 2. Launch sequence of a USAF Discoverer polar orbiting satellite at Vandenberg AFB. The Discoverer had a long list of 'firsts' to its credit: the first polar orbiting satellite, the first satellite to be stabilised in space on all three axes, the first to be manoeuvred in space, the first satellite capsule to be recovered from orbit, the first aerial recovery of a space capsule by the air-snatch technique. These qualities established the success of America's first operational reconnaissance satellite system.

United States Air Force

Weapons System 117L

The first question to be resolved was what type of camera system to use. An obvious choice was television, but this was rejected in August 1957 after study by RCA had shown that the resolution would be very poor. Instead, it was decided to develop a film scanning technique (by Eastman Kodak, Philco and CBS Laboratories) in which a conventional camera is used to photograph the scene; the film is then developed on board and scanned by a fine light beam. The resulting signal is transmitted to a receiving station on the ground, where it is used to build up a picture. Obviously the scanning process would degrade the picture quality to some extent, but it was expected to be far better than TV, and the other alternative, physical recovery of the film, still seemed a long way off. It must be remembered that at this time the art of building vehicles which could survive atmospheric re-entry was in its infancy, and the weight penalties for such systems were very high. It was decided, however, to develop a recoverable system as soon as the technology allowed [7].

The launch of Sputnik 1 in October 1957 demonstrated just how advanced Soviet rocketry was, and on 25 November Lockheed's budget for WS-117L was quadrupled [8]. In the meantime, the RAND Corporation had been carrying out further studies on satellite reconnaissance; in a report dated June 1956 entitled *Physical Recovery of Satellite Payloads: A Preliminary Investigation,* it suggested that a modified ICBM nosecone could be used to return camera film to Earth, while the November 1957 report *A Family of Recoverable Reconnaissance Satellites* held out great hopes for a physical recovery system. In January 1958 it was decided that such a system should be developed as soon as possible [7], and General Electric was contracted to produce the recoverable capsule [8]. That November the Department of Defense revealed that WS-117L now consisted of three elements: Discoverer, which would be used as a test bed for developing systems and concepts, Sentry (later to be renamed Samos) which would be the operational reconnaissance system, and Midas, which would be an early warning system to detect missile launches and warn of an attack [9]. The operational systems (Samos and Midas) were each to consist of 8 to 12 satellites in polar orbit, and it was planned that they should be on station by the mid-1960's.

The Agena Vehicle [10]

Lockheed's winning proposal for WS-117L consisted of a second stage to be placed atop an ICBM first stage. The instruments would be placed in the forward section of the vehicle, and on reaching orbit there would be no separation of launch vehicle second stage and payload, as is the usual case. This would allow the orbiting instruments to use the same command, guidance and control equipment as the second stage, giving, it was hoped, a considerable saving in weight and added flexibility. The first Agena was delivered to the USAF towards the end of 1958; it was 1.52 m in diameter and 5.94 m long. Fully fuelled it weighed 3,850 kg, while in orbit it weighed 770 kg. It was cylindrical, with a conical nose at the forward end, and the thrust chamber of the propulsion system protruding from the aft end. The instruments were mounted in the conical section, which carried as its apex the re-entry capsule. This was 84 cm in diameter and 69 cm long, and weighed 135 kg. The stage's rocket engine was the Bell Hustler, producing a thrust of 6,800 kg, and stabilisation was provided by two sets of cold gas reaction jets.

On reaching orbit the vehicle was to rotate through 180° to point backwards along the orbital path. The recovery sequence would be initiated by a command from the ground; first the nose of the craft would be pointed downwards at an angle of 60°, and then the capsule would be separated. It would immediately be spun about its axis to provide stability, and then a retrorocket would be fired to reduce its velocity and start re-entry, which would occur at an altitude of about 110 km. At an altitude of about 15 km the heat shield would be jettisoned, and a parachute deployed. Although the capsule would float, and it could be retrieved from the ocean, the primary method of recovery was to be the mid-air snatch technique. In this aircraft (initially C-119's were used,

Table 1. Discoverer Programme Satellites.

NAME	LAUNCH DATE (GMT)	LAUNCH VEHICLE	LIFE (days)	INCL. (deg)	PERIOD (min)	PERI-APO (km)
Discoverer 1	28 Feb 59	Thor-Agena A		89.7	96	163 - 968
Discoverer 2	13 Apr 59	Thor-Agena A		89.9	90.4	239 - 346
Discoverer 3	3 Jun 59	Thor-Agena A		failed to orbit		
Discoverer 4	25 Jun 59	Thor-Agena A		failed to orbit		
Discoverer 5	13 Aug 59	Thor-Agena A		80.0	94.19	217 - 739
Discoverer 6	19 Aug 59	Thor-Agena A		84.0	95.27	212 - 848
Discoverer 7	7 Nov 59	Thor-Agena A		81.64	94.70	159 - 847
Discoverer 8	20 Nov 59	Thor-Agena A		80.65	103.72	187 - 1679
Discoverer 9	4 Feb 60	Thor-Agena A		failed to orbit		
Discoverer 10	19 Feb 60	Thor-Agena A		failed to orbit		
Discoverer 11	15 Apr 60	Thor-Agena A		80.1	92.16	170 - 589
Discoverer 12	29 Jun 60	Thor-Agena A		failed to orbit		
Discoverer 13	10 Aug 60	Thor-Agena A	1.11	82.85	94.04	258 - 683
Discoverer 14	18 Aug 60	Thor-Agena A	1.12	79.65	94.55	186 - 805
Discoverer 15	13 Sep 60	Thor-Agena A		80.90	94.23	199 - 761
Discoverer 16	26 Oct 60	Thor-Agena B		failed to orbit		
Discoverer 17	12 Nov 60	Thor-Agena B	2.08	81.70	96.45	190 - 984
Discoverer 18	7 Dec 60	Thor-Agena B	3.12	81.50	93.66	243 - 661
Discoverer 19	20 Dec 60	Thor-Agena B		83.40	93.00	209 - 631
Discoverer 20	17 Feb 61	Thor-Agena B		80.91	95.41	288 - 786
Discoverer 21	18 Feb 61	Thor-Agena B		80.74	97.85	240 - 1069
Discoverer 22	30 Mar 61	Thor-Agena B		failed to orbit		
Discoverer 23	8 Apr 61	Thor-Agena B		82.31	94.09	295 - 651
Discoverer 24	8 Jun 61	Thor-Agena B		failed to orbit		
Discoverer 25	16 Jun 61	Thor-Agena B	2.08	82.11	90.87	222 - 409
Discoverer 26	7 Jul 61	Thor-Agena B	2.11	82.94	95.02	228 - 808
Discoverer 27	21 Jul 61	Thor-Agena B		failed to orbit		
Discoverer 28	3 Aug 61	Thor-Agena B		failed to orbit		
Discoverer 29	30 Aug 61	Thor-Agena B	2.10	82.14	91.51	152 - 542
Discoverer 30	12 Sep 61	Thor-Agena B	2.12	82.66	92.40	235 - 546
Discoverer 31	17 Sep 61	Thor-Agena B		82.70	90.86	235 - 396
Discoverer 32	13 Oct 61	Thor-Agena B	1.14	81.69	90.84	234 - 395
Discoverer 33	23 Oct 61	Thor-Agena B		failed to orbit		
Discoverer 34	5 Nov 61	Thor-Agena B		82.52	97.12	227 - 1011
Discoverer 35	15 Nov 61	Thor-Agena B	1.12	81.63	89.7	238 - 278
Discoverer 36	12 Dec 61	Thor-Agena B	4.08	81.21	91.82	241 - 484
Discoverer 37	13 Jan 62	Thor-Agena B		failed to orbit		
Discoverer 38	27 Feb 62	Thor-Agena B	4.06	82.23	90.04	208 - 341

Notes: 1. This table lists all satellites launched in the Discoverer Programme.
2. The lifetimes refer to the recoverable capsules. Lifetimes are quoted for those capsules which were recovered.
3. All launches were made from Vandenberg Air Force Base.

but these were replaced in 1961 by C-130's) trailing large trapeze-like devices would try to snag the capsule as it made its parachute descent. The aircraft would cross the capsule's path just above it, so that the cables of the recovery device, trailing behind and below the aircraft, would ensnare the parachute lines. If all went well the parachute would collapse and fold over, allowing capsule, parachute and recovery device to be hauled into the aircraft.

The Discoverer Programme [8, 11]

All launches in the Discoverer programme (see Table 1) were made from Vandenberg Air Force Base, California, using Thor rockets as their first stages. The plan was to place the satellites in near polar orbits, which would take them over virtually the whole of the Earth's surface. By placing them in orbits with periods of 90 to 95 minutes they could be recovered over the Pacific Ocean after one day on their seventeenth or eighteenth orbits, after two days on their thirty-second or thirty-third orbits, after three days on their forty-eighth or forty-ninth orbits, and so on.

The first launch took place on 28 February 1959 and the Agena went into an orbit with a perigee of 163 km and an apogee of 968 km. It carried no recoverable capsule, but was intended as a test of the Agena and its systems. Unfortunately a fault in the stabilisation system caused the craft to tumble violently in orbit. The second launch, on 13 April, was successful, and all seemed to be going well until a human error caused the re-entry sequence to be initiated too early, and the capsule descended far away from the recovery forces, over northern Norway. Ironically, all the mechanical systems appeared to have worked correctly, and there were reports of sightings of the descending capsule, but a search party was unable to locate it.

After a very promising start the Discoverer programme now entered a period of continuing frustration. The next two launches, on 3 and 25 June, failed to achieve orbit, and when Discoverer 5 actually made it to orbit on 13 August, improper orientation during retrofire sent the capsule into a higher orbit rather than back to Earth. Flight number 6, which was probably the first to carry photographic equipment, seemed to be going very smoothly; a good orbit was achieved on 19 August, and the retrofire and re-entry sequence was carried out according to plan on the seventeenth orbit. During the parachute descent, however, no homing signals were received from the capsule, and it and its cargo were never found. Things then began to get worse; Discoverer 7 could not be stablised in orbit, and a launch vehicle guidance error placed Discoverer 8 in an orbit with an apogee of 1,679 km. It was decided to try and recover the capsule on the fifteenth orbit, but the parachute did not seem to deploy correctly, and the capsule was not recovered.

The next two launches, on 4 and 19 February 1960, did not get into orbit, but on 15 April Discoverer 11 seemed to be working as planned. Re-entry was initiated on the seventeenth orbit, but its descent could not be tracked and it was lost. Discoverer 12 was another launch failure, but with number 13 the programme's luck changed. On 10 August it was placed in a 258 km to 683 km orbit, and

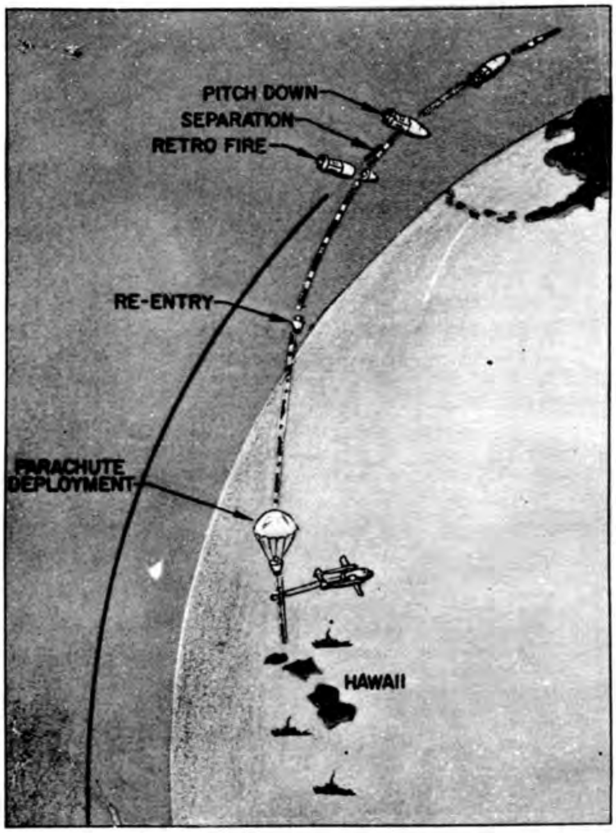


Fig. 3. Agena spacecraft capsule re-entry sequence from polar orbit begins near Alaska.

Kenneth W. Gatland

right on schedule on the seventeenth orbit the capsule was ejected and its retrorocket fired. Radar based in Hawaii, 450 km south west of its path, tracked it on its way down, and although heavy cloud precluded mid-air retrieval, it was soon spotted floating in the ocean, and picked up by Navy frogmen. This was the first object that had ever been recovered from space, a considerable technical achievement.

A week after the recovery, Discoverer 14 was launched. Launch vehicle and spacecraft performed perfectly, achieving a good orbit and ejecting their capsule on the seventeenth pass as planned. As it dropped through the 2,600 m altitude mark it was caught by a C-119 and hauled on board. After 16 months of trying a completely successful mission was accomplished, and whereas the USAF stressed that Discoverer 13 carried "no sensor equipment," no such statement was made for this mission. It seems quite likely that the US was analysing its first photographs of the Soviet Union taken from space by the end of August 1960.

Although a successful mission had been completed, there were still problems to be resolved. Discoverer 15, launched on 13 September, ejected its capsule but it landed outside the recovery area and was lost, while Discoverer 16 failed to reach orbit. This flight marked the introduction of the new Agena B; lengthened to 8.08 m to carry more propellants and with a new restartable engine it could place 950 kg in orbit. The next two missions were both complete successes, returning after two and three days in orbit respectively. Discoverer 19 was orbited on 20 December, but carried no recoverable capsule as it was a test of sensors for the Midas project.

The New Year got off to a bad start when Discoverer 20 could not be stabilised in orbit following launch on 17 February, but the next day all went well for Discoverer 21, another Midas test vehicle. The next three flights did not achieve their objectives, with numbers 22 and 24 failing to reach orbit, and incorrect orientation causing Discoverer 23's retrofire to send its capsule into a higher orbit instead of back to Earth.

The first recoveries of 1961 came with Discoverers 25 and 26, launched on 16 June and 7 July, each returning its capsule after two days, but then the next two flights were launch failures. This uneven record would continue through to the end of the programme in the Spring of 1962, with the next two flights (numbers 29 and 30) leading to capsule recoveries, followed by a flight on which the capsule could not be ejected, and then another success. The year ended with a launch failure, an orbital failure, a mid-air recovery and a retrieval from the sea, the last after four days in space. The final launches of the programme came on 13 January (a launch failure) and 27 February 1962 (a mid-air recovery after four days), bringing the total number of launches to 38. Of these 26 reached orbit, and of the 23 capsules they carried, 8 were recovered in mid-air and four from the sea. This record may not sound very impressive today, but fifteen years ago, when space vehicles were notoriously unreliable, it represented a considerable achievement. Most important of all, the programme had shown that the recovery of photographic film from space was feasible, and the indications were that when the "bugs" had been worked out of the system, it could be carried out on a routine basis.

Operational Reconnaissance System

The development by the Discoverer programme of the film recovery technique did not mean that the radio transmission had been abandoned, for each system had its advantages and disadvantages. The film recovery method gave much better resolution, and showed more detail of what was on the ground, but the weight penalty of carrying a re-entry capsule was high, and meant that only a small quantity of film could be carried. Radio transmission, on the other hand, produced poorer resolution, but many more photographs could be taken on a mission. It also had the advantage that its photographs could be analysed as soon as they had been transmitted to the ground, probably within a couple of hours of them actually being taken, whereas no shots could be studied from a recovery mission until the flight was complete, the capsule had been recovered and the film flown to Washington.

There were three main tasks for reconnaissance satellites in the early 1960's; the first was to get a detailed look at the Soviet ICBM, the SS-6, which was thought to be deployed in large numbers. By studying its ground handling, the number of people required to service it, etc., a good estimate could be made of how quickly an attack could be mounted, and how vulnerable it might be to a first strike. Another important question was how many missiles were deployed, and was the "Missile Gap" really as bad as some people claimed (it was not!). To do this a survey of most of the Soviet Union was required, but as the missiles were so big, a launch site would show up clearly, and good resolution would not be required. The third application was to map the whole of the Soviet Union, to provide targeting data for US missiles (it was discovered when this was complete that the positions of cities shown on Soviet maps were deliberately falsified, with their locations as much as 15 km out [12]). Again, good resolution was not as important as the number of flights necessary to cover the ground.

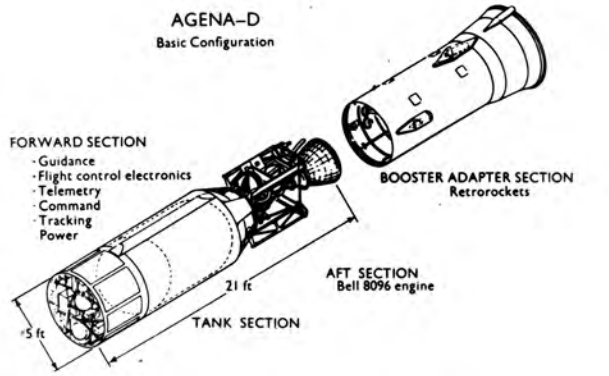
These factors led to the decision to develop both film recovery and radio transmission satellites as two complementary programmes. Because of their applications, the radio transmission vehicles are usually referred to as area survey satellites, and the film recovery vehicles are referred to as close look satellites.

The Area Survey Satellites

At about the time of the early Discoverer launches, tests were being carried out of the radio transmission system from aircraft. This system was being developed by Eastman Kodak (the camera) and CBS Laboratories (the film scanner), and a close relation, built by the same companies, was to find another application in Moon photography in the Lunar Orbiter series of spacecraft in 1966 and 1967 [11]. The ability to use aircraft as test vehicles, instead of the space vehicles that the recovery system required, meant that these tests could be carried out much more quickly and at far less cost. As a consequence, the first operational area survey satellite was ready for launch only two months after the Discoverer programme had made its first recovery in August 1960. That two-month period saw several milestones in the reconnaissance programme. In early September the programme's name was changed from Sentry to Samos, an acronym for Satellite and Missile Observation System, and soon afterwards it was given a new priority under an Air Force reorganisation. The programme was moved under the direct control of the Secretary of the Air Force, an unprecedented move in the history of USAF developments [13]. Following this, requests for proposals were issued for the close-look satellite, code named E-6 (the area survey satellites were code named E-5), with bids to be in by 13 October. The winning contractor was to deliver a prototype nine months after the start of work, half the normal period for such a complex system [14].

The first area survey satellite, Samos 1, was launched on 11 October 1960, see Table 2. The Atlas-Agena A vehicle's first stage performed as planned, but although the second stage ignited the craft did not reach orbit. At the time the USA was engaged in an all-out bid to close the "Missile Gap," and most of the rockets that came off the Atlas production line were earmarked for deployment as ICBM's, so it was three months until the next Samos launch, but this time a success was recorded. On 31 January 1961 Samos 2 was placed in an orbit with a perigee of 474 km and an apogee of 557 km, giving it a period of very nearly 95 minutes. In orbit it weighed 1,860 kg, of which about 150 kg were instruments, and it operated in space for a month. The success of this flight can be judged from the way US estimates of Soviet ICBM strengths were reduced in the following months, from the original 120 to 60 in June, and then further to only 14 in September [11], and the increased confidence with which they were expressed. The next launch, Samos 3 on 9 September, used the new Agena B upper stage, but failed when the vehicle exploded on the pad.

With the success of the growing US reconnaissance effort, the Soviet Union had been mounting a propaganda campaign against American "militarisation of space," and it was presumably in response to this that the Department of Defense decided to change its policy on the amount of information made public about its launches. It was decided that the programme under which a launch was made should not be identified, and only an announcement of the launch vehicle type and whether orbit had been achieved would be made. However, tables of orbital parameters are issued by the Royal Aircraft Establishment at Farnborough, so even if the USAF does not give these details (as it sometimes doesn't) they are always available to the public. Armed with these, and a knowledge of the sort of orbit required for a given mission and the type of launch vehicle used, it is possible to identify those launches which form part of the reconnaissance programmes with a good degree of certainty. Thus when the first of these unidentified launches was made on 22 November 1961 using an Atlas-Agena B launch vehicle, it was fairly clear that this was a Samos mission. This flight failed to reach orbit, but the next one, launched a month later, was placed in a 244 km to 702 km orbit. Before the advent of satellites it had been expected that the minimum altitude that a



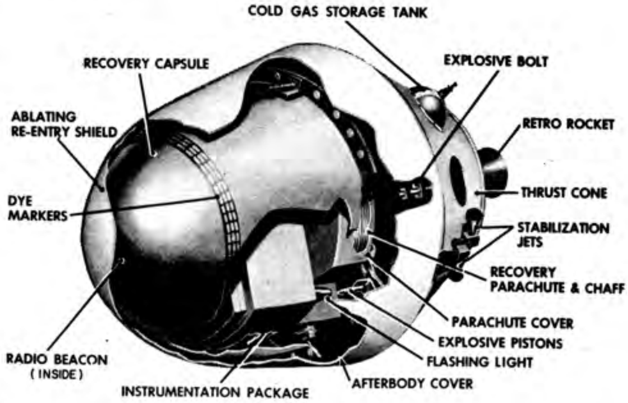


Fig. 4. The orbiting Agena stage upon which the U.S. Air Force built the first family of reconnaissance satellites. Camera equipment and re-entry capsule were in the nose section (not shown here). *Below,* 300 lb. (136 kg) re-entry capsule.

Lockheed Missile and Space Systems/General Electric of USA

satellite could use which would not decay in a matter of hours would be about 450 km, but the early spacecraft had shown that the upper atmosphere was less dense than expected, and altitudes as low as 150 km could be used for flights of a few weeks. This would, of course, benefit the reconnaissance satellites, as reducing their altitudes would increase their ground resolutions and allow their transmission systems to use higher data rates. The launch of 22 December seems to have been the first to test the lower altitudes; as the programme progressed the perigee heights would average about 180 km and the apogees in the 300 km to 400 km range.

By the beginning of 1962 the weight of the photographic system had been reduced enough to allow a change to the Thor-Agena B launch vehicle [15], which could place about 1,000 kg in orbit. The first of these launches was made on 21 February, with the Agena going into a 167 km to 374 km orbit, typical of those that were to follow. All the succeeding launches involved Thor-based vehicles, and the reliability problems that plagued the Discoverer programme seemed to have been cured, for there were to be eighteen more successful launches before the next failure.

As 1962 progressed a transition was made from the Agena B to the Agena D, with the first launch of the new variant on 28 June and the last of the old on 24 November. The new stage had a restartable engine which could be fired from time to time to raise its orbit and prolong its life [15]. The pace of launches built up in 1962, with eighteen successes and no failures marked up by the end of the year, indicating the maturity of the programme and the importance attached to its results.

Table 2. Area Survey Satellites.

NAME	LAUNCH DATE (GMT).	LAUNCH VEHICLE	LIFE (days)	INCL. (deg)	PERIOD (min)	PERI-APO (km)
Samos 1	11 Oct 60	Atlas-Agena A		failed	to orbit	
Samos 2	31 Jan 61	Atlas-Agena A	4646	97.40	94.97	474 - 557
Samos 3	9 Sep 61	Atlas-Agena B		failed	to orbit	
none	22 Nov 61	Atlas-Agena B		failed	to orbit	
1961-αλ	22 Dec 61	Atlas-Agena B	235	89.6	94.1	244 - 702
1962-δ	21 Feb 62	Thor-Agena B	16	81.97	90.0	167 - 374
1962-λ	18 Apr 62	Thor-Agena B	40	73.48	90.9	200 - 441
1962-ρ	28 Apr 62	Thor-Agena B	28	73.11	91.1	180 - 475
1962-φ	30 May 62	Thor-Agena B	12	74.10	89.7	199 - 319
1962-χ	2 Jun 62	Thor-Agena B	26.9	74.26	90.5	211 - 385
1962-αβ	23 Jun 62	Thor-Agena B	14.7	75.09	89.58	213 - 293
1962-αγ	28 Jun 62	Thor-Agena D	78	76.04	93.6	211 - 689
1962-αη	21 Jul 62	Thor-Agena B	24	70.29	90.42	208 - 381
1962-αθ	28 Jul 62	Thor-Agena B	27	71.09	90.64	225 - 386
1962-ακ	2 Aug 62	Thor-Agena D	24	82.25	90.77	204 - 418
1962-ασ	29 Aug 62	Thor-Agena D	12	65.21	90.38	187 - 400
1962-αχ	17 Sep 62	Thor-Agena B	62.2	81.84	93.33	204 - 668
1962-ββ	29 Sep 62	Thor-Agena D	14	65.40	90.30	203 - 376
1962-βε	9 Oct 62	Thor-Agena B	37.3	81.96	90.96	213 - 427
1962-βο	5 Nov 62	Thor-Agena B	27	74.98	90.71	208 - 409
1962-βρ	24 Nov 62	Thor-Agena B	18	65.14	89.92	204 - 337
1962-βσ	4 Dec 62	Thor-Agena D	3	65.1	89.16	194 - 273
1962-βφ	14 Dec 62	Thor-Agena D	25.0	70.97	90.46	199 - 392
1963-02	7 Jan 63	Thor-Agena D	16.3	82.23	90.54	205 - 399
none	28 Feb 63	TAT-Agena D		failed	to orbit	
none	18 Mar 63	TAT-Agena D		failed	to orbit	
1963-07	1 Apr 63	Thor-Agena D	25.0	75.40	90.66	201 - 408
none	26 Apr 63	Thor-Agena D		failed	to orbit	
1963-16	18 May 63	TAT-Agena D	8	74.54	91.12	153 - 497
1963-19	13 Jun 63	TAT-Agena D	29.1	81.87	90.67	192 - 419
1963-25	27 Jun 63	TAT-Agena D	29.7	81.6	90.5	196 - 396
1963-29	19 Jul 63	Thor-Agena D	25.8	82.86	90.44	194 - 387
1963-32	31 Jul 63	TAT-Agena D	12.0	74.95	90.4	157 - 411
1963-34	25 Aug 63	TAT-Agena D	18.6	75.01	89.4	161 - 320
*1963-35	29 Aug 63	Thor-Agena D	69.7	81.89	90.80	292 - 324
1963-37	23 Sep 63	TAT-Agena D	18.2	74.90	90.63	161 - 441
*1963-42	29 Oct 63	TAT-Agena D	83.51	89.90	90.84	279 - 345
none	9 Nov 63	Thor-Agena D		failed	to orbit	
1963-48	27 Nov 63	Thor-Agena D	17.3	69.99	90.2	175 - 386
*1963-55	21 Dec 63	TAT-Agena D	18.0	64.94	89.96	176 - 355
1964-08	15 Feb 64	TAT-Agena D	23.0	74.95	90.86	179 - 444
none	24 Mar 64	TAT-Agena D		failed	to orbit	
1964-22	27 Apr 64	TAT-Agena D	28.19	79.93	90.77	178 - 446
1964-27	4 Jun 64	TAT-Agena D	13.94	79.96	90.27	149 - 429
1964-32	19 Jun 64	TAT-Agena D	26.81	85.0	90.95	176 - 462
1964-37	10 Jul 64	TAT-Agena D	26.52	84.98	91.00	180 - 461
1964-43	5 Aug 64	TAT-Agena D	26.0	79.96	90.71	182 - 436
1964-56	14 Sep 64	TAT-Agena D	21.7	84.96	90.88	172 - 466
1964-61	5 Oct 64	TAT-Agena D	20.50	79.97	90.75	182 - 440
1964-67	17 Oct 64	TAT-Agena D	17.27	74.99	90.59	189 - 416
1964-71	2 Nov 64	TAT-Agena D	25.33	79.95	90.70	180 - 448
1964-75	18 Nov 64	TAT-Agena D	17.45	70.02	89.71	180 - 339
1964-85	19 Dec 64	TAT-Agena D	26.06	74.97	90.46	183 - 410
1964-87	21 Dec 64	TAT-Agena D	21.64	70.08	89.5	238 - 264

Early in the next year a second generation of area survey satellites was introduced, with the first launch on 28 February. By placing three solid propellant boosters on the Thor first stage the payload could be increased to 1,500 kg, which would allow the satellite to carry more film and consumables for longer stays in orbit. The first launch of the new vehicle, known as the TAT-Agena D (standing for Thrust Augmented Thor-Agena D) failed, as did the second, but the third attempt, on 18 May, was a success. Following this flight the use of the older generation was phased out, with its last launch on 27 November. The other development of 1963 was the introduction of subsatellites for electronic intelligence ("ferret") missions. These small craft, weighing about 60 kg, are carried into orbit attached to their main payloads, but once in orbit they are separated and placed in their own higher orbits (they will be described in more detail in a later section). Three launches in 1963 carried these subsatellites, but then they were assigned to the close look vehicles for the next three years. In all, seventeen launches were made during the year, of which thirteen reached orbit.

By now operations had become routine, with both 1964 and 1965 showing a record of thirteen successes and one failure, but 1966 saw the introduction of a third generation launch vehicle and spacecraft. The new spacecraft carried infra-red scanners in addition to its cameras, which allowed photographs to be taken on night passes, and they were equipped with the new Space-Ground Link System [16], which used a 1.5 m unfurlable antenna and enabled pictures to be transmitted to the ground at a much higher rate [17]. To boost this satellite a new launch vehicle was introduced, the LTTAT-Agena D (for Long Tank Thrust Augmented Thor-Agena D). The propellant tanks of the Thor were lengthened, and instead of tapering towards the nose a constant diameter was maintained, giving it a payload capability

Table 2. Area Survey Satellites/contd.

NAME	LAUNCH DATE (GMT)	LAUNCH VEHICLE	LIFE (days)	INCL. (deg)	PERIOD (min)	PERI-APO (km)
1965-02	15 Jan 65	TAT-Agena D	25.0	74.95	90.52	180 - 420
1965-13	25 Feb 65	TAT-Agena D	20.92	75.08	90.07	177 - 377
1965-26	25 Mar 65	TAT-Agena D	10.1	96.08	89.06	186 - 265
1965-33	29 Apr 65	TAT-Agena D	26.5	85.04	91.05	178 - 473
1965-37	18 May 65	TAT-Agena D	28.24	75.01	89.71	198 - 331
1965-45	9 Jun 65	TAT-Agena D	12.58	75.07	89.84	176 - 362
1965-57	19 Jul 65	TAT-Agena D	29.25	85.05	91.01	182 - 464
1965-67	17 Aug 65	TAT-Agena D	54.40	70.04	90.37	180 - 407
none	2 Sep 65	TAT-Agena D		failed	to orbit	
1965-74	22 Sep 65	TAT-Agena D	18	80.01	90.04	191 - 364
1965-79	5 Oct 65	TAT-Agena D	24.01	75.05	89.75	203 - 323
1965-86	28 Oct 65	TAT-Agena D	19.81	74.97	90.54	176 - 430
1965-102	9 Dec 65	TAT-Agena D	16.78	80.04	90.72	183 - 437
1965-110	24 Dec 65	TAT-Agena D	26.59	80.01	90.83	178 - 446
1966-07	2 Feb 66	TAT-Agena D	24.67	75.05	90.64	185 - 425
1966-18	9 Mar 66	TAT-Agena D	19.83	75.03	90.59	178 - 432
1966-29	7 Apr 66	TAT-Agena D	18.43	75.06	89.56	193 - 312
none	3 May 66	TAT-Agena D		failed	to orbit	
1966-42	24 May 66	TAT-Agena D	16	66.04	89.00	179 - 271
1966-55	21 Jun 66	TAT-Agena D	22	80.10	90.15	194 - 367
1966-72	9 Aug 66	LTTAT-Agena D	32.20	100.12	89.35	194 - 287
1966-85	20 Sep 66	TAT-Agena D	21.90	85.13	90.87	188 - 442
1966-102	8 Nov 66	TAT-Agena D	20.6	100.09	89.42	172 - 318
1967-02	14 Jan 67	TAT-Agena D	18.7	80.07	90.13	180 - 380
1967-15	22 Feb 67	TAT-Agena D	17.02	80.03	90.12	180 - 380
1967-29	30 Mar 67	TAT-Agena D	17.65	85.03	89.45	167 - 326
*1967-43	9 May 67	LTTAT-Agena D	64.62	85.10	94.36	200 - 777
*1967-62	16 Jun 67	LTTAT-Agena D	33.16	80.02	89.97	181 - 367
1967-76	7 Aug 67	LTTAT-Agena D	24.85	79.94	89.72	174 - 346
1967-87	15 Sep 67	LTTAT-Agena D	18.69	80.07	89.95	150 - 389
*1967-109	2 Nov 67	LTTAT-Agena D	29.83	81.53	90.47	183 - 410
1967-122	9 Dec 67	LTTAT-Agena D	15	81.65	88.45	158 - 237
*1968-08	24 Jan 68	LTTAT-Agena D	33.54	81.48	90.55	176 - 430
*1968-20	14 Mar 68	LTTAT-Agena D	26.22	83.01	90.20	178 - 391
1968-39	1 May 68	LTTAT-Agena D	14	83.05	88.58	164 - 243
*1968-52	20 Jun 68	LTTAT-Agena D	25	84.99	89.75	193 - 326
1968-65	7 Aug 68	LTTAT-Agena D	19.45	82.11	88.60	152 - 257
*1968-78	18 Sep 68	LTTAT-Agena D	19.25	83.02	90.12	167 - 393
1968-98	3 Nov 68	LTTAT-Agena D	19.99	82.15	88.90	150 - 288
*1968-112	12 Dec 68	LTTAT-Agena D	15.65	81.02	88.67	169 - 248
*1969-10	5 Feb 69	LTTAT-Agena D	18.86	81.54	88.70	178 - 239
*1969-26	19 Mar 69	LTTAT-Agena D	4.35	83.04	88.73	179 - 241
*1969-41	2 May 69	LTTAT-Agena D	21.35	64.97	89.54	179 - 326
1969-63	24 Jul 69	LTTAT-Agena D	30.44	74.98	88.49	178 - 220
*1969-79	22 Sep 69	LTTAT-Agena D	19.74	85.03	88.83	178 - 253
1969-105	4 Dec 69	LTTAT-Agena D	36.26	81.48	88.61	159 - 251
*1970-16	4 Mar 70	LTTAT-Agena D	21.98	88.02	88.76	167 - 257
*1970-40	20 May 70	LTTAT-Agena D	27.53	83.00	88.62	162 - 247
1970-54	23 Jul 70	LTTAT-Agena D	26.99	60.00	90.04	158 - 398
*1970-98	18 Nov 70	LTTAT-Agena D	22.78	82.99	88.70	185 - 232
none	17 Feb 71	LTTAT-Agena D		failed	to orbit	
1971-22	24 Mar 71	LTTAT-Agena D	18.81	81.52	88.56	157 - 246
*1971-76	10 Sep 71	LTTAT-Agena D	25.02	74.95	88.48	156 - 244
1972-32	19 Apr 72	LTTAT-Agena D	22.77	81.48	88.85	155 - 277
1972-39	25 May 72	LTTAT-Agena D	10.20	96.34	89.17	158 - 305

Notes:
1. This table lists all satellites with the characteristics of area survey missions.
2. Launches by Thor-Agena D, TAT-Agena D and LTTAT-Agena D which failed to reach orbit may be ferret missions. It is not possible to discriminate between area survey and ferret missions when only the launch vehicle, and not the intended orbit, is known.
3. Those launches marked with an asterisk carried ferret subsatellites which were ejected into separate orbits.
4. All launches were made from Vandenberg Air Force Base.

of 2,000 kg. The first launch of the new combination was made on 9 August, and the satellite operated for 32 days before decaying, but it appears that some problems may have ocurred, since nine months were to pass before the next launch of this type. In the meantime the area survey function was carried out by the second generation craft, and by the end of the year a total of nine launches had been made, all but one succeeding. This downward trend in the number of launches made each year was to continue, and there appear to be two main reasons for this. Firstly, the improved sensors on board the spacecraft gave better coverage, so less flights were required to observe a given area. Secondly, by now one assumes that a complete survey of the Soviet Union (and other interesting countries) had been made, and a detailed inventory of Russian weapon deployments had been compiled. In this case area survey flights would only be required periodically, to check on changes to the scene.

The first launches of 1967 used the second generation vehicle, but from 9 May onwards all launches used the new LTTAT-Agena D. With the new vehicle came the re-introduction of ferret subsatellites to the area survey programme, a function that was to continue until the end of the programme. A total of nine launches were made during the year, and eight the next, the last of which carried a new type of sub-

satellite into orbit on 12 December. The first launch of 1969, on 5 February, also carried one, and they both went into high circular orbits, but their possible applications will be discussed later. In 1969 the launch total dropped to six, and the next year to four. The year of 1971 was noteworthy for two reasons – the programme had its first launch failure for nearly five years (and its last), and the appearance of Big Bird. The latter was an entirely new generation of reconnaissance satellite, combining the area survey and close-look functions in a single craft, and within a year of its first launch in June 1971 the area survey programme had ended. In thirteen years 109 launches had been made, and of these 98 succeeded in placing their payloads in orbit, giving a launch reliability of 90%.

Close-Look Satellites

The recovery of Discoverer 13's capsule in August 1960 was the signal for the USAF to press ahead with the development of the operational close-look system. Within three months proposals from industry had been requested, received and evaluated, with the result that contracts were awarded to General Electric for the recoverable capsule and to Eastman Kodak for the camera system [18]. This vehicle would use the Atlas-Agena B combination and weigh around 2,000 kg in orbit, twice the weight of the later Discoverers.

It was reported in February 1962 that the first two satellites had been delivered to the USAF, one for checkout of booster compatibility and ground handling, and one for launch [19]. It was placed in orbit on 7 March (see Table 3), but in the absence of official announcements it is hard to judge the degree of success that this flight achieved. Its orbit, from 251 km to 676 km, was higher than subsequent missions: this could have been intentional, if the first mission was designed to perform extensive checks of the satellite's systems, with photographic resolution sacrificed in favour of longer life, or it could simply have been a launch vehicle guidance error. The main spacecraft stayed in orbit for fifteen months, but it is not clear from the public record if a capsule was ejected or not. The Agena B vehicles followed the design of the Discoverers, with the retro-rocket attached to the capsule, so that its firing, which occurred after separation of the capsule from the main spacecraft, would not alter the orbit of the main vehicle, which would remain in space until it decayed due to atmospheric drag.

The next two launches were made on 26 April and 17 June, but very few details of their orbits have ever been made public. Their orbital lifetimes were two days and one day respectively, which line up with those of later flights, so whatever the reasons for the 7 March flight's high orbit, it was not repeated. Three more launches were made in the year (for which full orbital details are available), but then there was a break of eight months until 12 July 1963, when the first of the second generation close-look vehicles was launched. These used the Agena D stage, and the main change from the older type was in the means of retrofire. The engine of the Agena D is restartable and was used to carry out retrofire [15], which gave a significant weight saving over the earlier configuration. It also meant that when the engine was fired to initiate re-entry, the main spacecraft was also decelerated and so the orbital lifetime quoted is also that of the recoverable capsule.

Four close-look satellites were placed in orbit in the six month period to the end of 1963, and this launch rate was maintained through 1964 (nine successes out of ten attempts) and 1965 (eight successes out of nine attempts). All these flights had similar characteristics – a perigee of about 150 km, an apogee of about 300 km, an inclination between 90° and 110°, and a lifetime of about three to five days. In addition, some of these satellites ejected ferret subsatellites (two in 1964 and three in 1965), a function that had previously been performed by the area survey programme.

In 1966 a third generation of close-look satellites was introduced, using the new Titan 3B- Agena D launcher. They weighed about 3,000 kg in orbit, and the extra capacity was used to carry more film and consumables, and a new multi-spectral camera built by the Itek Corporation [16]. As will be described later, the new camera was designed to photograph the same scene in several wavebands simultaneously and by comparing the different images it was hoped that objects hidden by camouflage could be indentified. The last Atlas-Agena D satellite was launched on 4 June 1967, and with the retirement of the old type of spacecraft the job of carrying ferret subsatellites was transferred back to the area survey programme.

The orbit used by the third generation satellites is slightly different from that of the older type, with a perigee close to 135 km and an apogee in the region of 400 km. Atmospheric drag at altitudes like 135 km is quite marked and the satellites must use their Agena engines often to stay in orbit. Despite this, their lifetimes have increased over the years, as can be seen from Fig. 5 and as a consequence the number of launches per year has dropped. In each of the years 1967 to 1972 there were close-look satellites in orbit for approximately ninety days but the number of launches needed to achieve this dropped from nine in 1967 to three in 1972.

Unlike the area survey programme the launching of close-look satellites did not end when the Big Bird system became operational in mid-1972. Figure 6 shows the flight histories of close-look and Big Bird satellites for 1971 through 1976, and it can be seen that most of the launches came in pairs; the first is a Big Bird, and near the end of its life or soon after it decays a close-look vehicle is launched. From this it would appear that most of the close-look craft are used to fill in the gaps in coverage of Big Birds. One notable exception to this came in 1974. On 5 June a Titan 3B-Agena D was launched, just about halfway through the life of a Big Bird that had been launched on 10 April. The launch failed, but another was made the next day, and this was a success. Obviously the Air Force was very keen to observe something that June; possibly it was the results of the explosion of India's first nuclear device on 18 May [20]. The Big Bird decayed on 28 July, and it was followed in the normal way by a close-look satellite on 14 August. In contrast to this the two launch failures of 20 May 1972 and 26 June 1973 were not followed up by new attempts; it is probable that rather than make new Titan 3B-Agena D launches it was decided to wait for the next Big Birds.

One other application that involved the Titan 3B-Agena D type of satellite was in connection with the US Navy's ocean surveillance programme. In testimony before the Senate in 1973 it was revealed that the Navy had been using surveillance data supplied by the USAF since 1971 [21]. The specific satellites were not identified, but it was implied that they were modified versions of the third-generation close-look vehicles. The orbits used by the satellites launched during this period all conformed very closely to the norm, so just which ones were involved in this project remains unresolved.

At the time of writing the close-look programme is still in progress. By the end of 1976, 93 launches had been made, of which 92% were successful, placing 86 satellites in orbit.

The 'Big Bird' Programme

During the late 1960's, while the third generation area survey and close-look satellites were in regular service, a new, fourth generation reconnaissance vehicle was under development that would perform both their functions. Like its predecessors, it is built by Lockheed and based on the Agena, but in a considerably modified and enlarged form. Measuring 15 m long and 3 m in diameter, and weighing 13,000 kg in orbit [17], it has been given the unofficial (but widely used) name 'Big Bird.'

Table 3. Close-Look Satellites.

NAME	LAUNCH DATE (GMT)	LAUNCH VEHICLE	LIFE (days)	INCL. (deg)	PERIOD (min)	PERI-APO (km)
1962-η	7 Mar 62	Atlas-Agena B	457.1	90.89	93.9	251 - 676
1962-π	26 Apr 62	Atlas-Agena B	2	74.1 ?	90 ?	?
1962-ψ	17 Jun 62	Atlas-Agena B	1	?	?	?
1962-$\alpha\varsigma$	18 Jul 62	Atlas-Agena B	9	96.12	88.73	184 - 236
1962-$\alpha\lambda$	5 Aug 62	Atlas-Agena B	1	96.30	88.62	205 - 205
1962-$\beta\kappa$	11 Nov 62	Atlas-Agena B	1	96.00	88.65	206 - 206
1963-28	12 Jul 63	Atlas-Agena D	5.2	95.37	87.80	164 - 164
1963-36	6 Sep 63	Atlas-Agena D	7.05	94.37	89.06	168 - 263
1963-41	25 Oct 63	Atlas-Agena D	4.0	99.05	88.99	144 - 332
1963-51	18 Dec 63	Atlas-Agena D	1.28	97.89	88.48	122 - 266
1964-09	25 Feb 64	Atlas-Agena D	4	95.66	88.24	173 - 190
1964-12	11 Mar 64	Atlas-Agena D	4.3	95.73	88.2	163 - 203
1964-20	23 Apr 64	Atlas-Agena D	5.2	103.56	89.40	150 - 336
1964-24	19 May 64	Atlas-Agena D	2.9	101.12	89.69	141 - 380
*1964-36	6 Jul 64	Atlas-Agena D	2.0	92.89	89.20	121 - 346
1964-45	14 Aug 64	Atlas-Agena D	8.8	95.52	89.0	149 - 307
1964-58	23 Sep 64	Atlas-Agena D	4.78	92.91	89.00	145 - 303
none	8 Oct 64	Atlas-Agena D		failed to orbit		
*1964-68	23 Oct 64	Atlas-Agena D	5.06	95.55	88.6	139 - 271
1964-79	4 Dec 64	Atlas-Agena D	1.2	97.02	89.69	158 - 357
1965-05	23 Jan 65	Atlas-Agena D	5.2	102.5	88.85	146 - 291
1965-19	12 Mar 65	Atlas-Agena D	4.98	107.69	88.51	155 - 247
*1965-31	28 Apr 65	Atlas-Agena D	5.14	95.60	88.95	180 - 259
1965-41	27 May 65	Atlas-Agena D	5.11	95.78	88.67	149 - 267
*1965-50	25 Jun 65	Atlas-Agena D	4.9	107.64	88.78	151 - 283
none	12 Jul 65	Atlas-Agena D		failed to orbit		
*1965-62	3 Aug 65	Atlas-Agena D	4.11	107.47	89.06	149 - 307
1965-76	30 Sep 65	Atlas-Agena D	4.70	95.60	88.77	158 - 264
1965-90	8 Nov 65	Atlas-Agena D	2.92	93.88	88.74	145 - 277
1966-02	19 Jan 66	Atlas-Agena D	3.88	93.89	88.51	154 - 246
1966-12	15 Feb 66	Atlas-Agena D	7.44	96.54	89.00	148 - 293
1966-22	18 Mar 66	Atlas-Agena D	4.92	101.01	88.87	152 - 284
1966-32	19 Apr 66	Atlas-Agena D	6	116.95	89.94	145 - 398
*1966-39	14 May 66	Atlas-Agena D	6	110.55	89.40	133 - 358
1966-48	3 Jun 66	Atlas-Agena D	6.17	87.01	88.87	143 - 288
1966-62	12 Jul 66	Atlas-Agena D	7	95.52	88.25	137 - 236
1966-69	29 Jul 66	Titan 3B-Agena D	7	94.12	88.58	158 - 250
*1966-74	16 Aug 66	Atlas-Agena D	7.5	93.24	89.58	146 - 358
*1966-83	16 Sep 66	Atlas-Agena D	6	93.98	89.37	148 - 333
1966-86	28 Sep 66	Titan 3B-Agena D	9.06	93.98	89.01	151 - 296
1966-90	12 Oct 66	Atlas-Agena D	8.46	90.88	88.99	181 - 258
1966-98	2 Nov 66	Atlas-Agena D	7.2	90.96	89.20	159 - 305
1966-109	5 Dec 66	Atlas-Agena D	8.2	104.63	89.77	137 - 388
1966-113	14 Dec 66	Titan 3B-Agena D	9	109.56	89.58	138 - 368
1967-07	2 Feb 67	Atlas-Agena D	9	102.96	89.47	136 - 357
1967-16	24 Feb 67	Titan 3B-Agena D	10.15	106.98	90.02	135 - 414
none	26 Apr 67	Titan 3B-Agena D		failed to orbit		
1967-50	22 May 67	Atlas-Agena D	8.18	91.49	88.82	135 - 293
1967-55	4 Jun 67	Atlas-Agena D	8.17	104.88	90.57	149 - 456
1967-64	20 Jun 67	Titan 3B-Agena D	10.22	111.40	89.01	127 - 325
1967-79	16 Aug 67	Titan 3B-Agena D	13	111.88	90.43	142 - 449

The first hint of the existence of Big Bird, or Program 467 as it is officially known, came in June 1969 with the cancellation of the USAF's Manned Orbital Laboratory (MOL) project. The main aim of this programme had been to provide an orbital platform from which men could direct reconnaissance activities in real-time. It was thought that a man in a space station could use his discriminatory powers to great advantage when carrying out an area survey type of role, and when he spotted something of interest he could direct the high resolution camera on board to photograph the scene in detail. In this way, more comprehensive coverage than the current unmanned satellites gave could be achieved, and there would be an added advantage. Once a region requiring detailed photography has been identified from an area survey flight, there is a delay before a close-look mission can be set up and launched, but if both the area survey and close-look missions are performed by the same vehicle (as in MOL), the high resolution photography can be made very soon after a target has been chosen. Plans called for crews to make month-long stays on MOL, returning the exposed films to Earth in capsules when necessary. The Russians have a direct analogue of this in their Salyut station, but while it was pushed through to operational (if somewhat limited) use, MOL's growing cost and the financial pressure of the Vietnam war caused its cancellation. Considering the great importance placed on strategic reconnaissance, the USAF must only have been willing to abandon MOL if they had had an unmanned replacement well under way. When the first Big Bird was launched two years later, it was obvious that this was it.

Big Bird satellites are the largest military spacecraft developed by the United States, and their size dictates the use of the Titan 3D launcher. They carry two imaging systems, one a giant high resolution camera developed by Perkin-Elmer Corporation for close-look photography, and the other a development of Eastman Kodak's area survey camera with a new film scanner [22]. It has also been suggested that they may carry side-looking radar [16], which produces far better resolution than conventional radar but uses the same frequencies and thus has the same cloud penetrating capabilities. Six recoverable capsules are carried, and at regular intervals they are loaded with exposed film and returned to Earth [23], while the radio transmissions are handled by a 6 m unfurlable antenna [24].

The first launch was planned for the end of 1970, but problems with the camera system delayed it until 15 June 1971 [16]. It was placed in an orbit with a perigee of 184 km and an apogee 300 km (see Table 4), which is typical of area survey type missions. Its orbital inclination (96°) was chosen so that it covered the same areas each day at the

NAME	LAUNCH DATE (GMT)	LAUNCH VEHICLE	LIFE (days)	INCL. (deg)	PERIOD (min)	PERI-APO (km)
1967-90	19 Sep 67	Titan 3B-Agena D	10.23	106.10	89.75	122 - 401
1967-103	25 Oct 67	Titan 3B-Agena D	9	111.57	90.15	136 - 429
1967-121	5 Dec 67	Titan 3B-Agena D	11.18	109.55	90.16	137 - 430
1968-05	18 Jan 68	Titan 3B-Agena D	17.13	111.52	89.91	138 - 404
1968-18	13 Mar 68	Titan 3B-Agena D	11	99.87	89.87	128 - 407
1968-31	17 Apr 68	Titan 3B-Agena D	12	111.51	90.10	134 - 427
1968-47	5 Jun 68	Titan 3B-Agena D	12.2	110.52	90.31	123 - 456
1968-64	6 Aug 68	Titan 3B-Agena D	9	110.00	89.85	142 - 395
1968-74	10 Sep 68	Titan 3B-Agena D	15	106.06	89.82	125 - 404
1968-99	6 Nov 68	Titan 3B-Agena D	14	106.0	89.73	130 - 390
1968-108	4 Dec 68	Titan 3B-Agena D	8	106.24	93.30	136 - 736
1969-07	22 Jan 69	Titan 3B-Agena D	12	106.15	97.04	142 - 1090
1969-19	4 Mar 69	Titan 3B-Agena D	14	92.00	90.50	134 - 461
1969-39	15 Apr 69	Titan 3B-Agena D	15	108.76	89.96	135 - 410
1969-50	3 Jun 69	Titan 3B-Agena D	11.2	110.00	90.04	137 - 414
1969-74	22 Aug 69	Titan 3B-Agena D	16	108.00	89.51	133 - 366
1969-95	24 Oct 69	Titan 3B-Agena D	15	108.04	93.39	136 - 740
1970-02	14 Jan 70	Titan 3B-Agena D	18	109.96	89.69	134 - 383
1970-31	15 Apr 70	Titan 3B-Agena D	21	110.97	89.70	130 - 388
1970-48	25 Jun 70	Titan 3B-Agena D	11	108.87	89.70	129 - 389
1970-61	18 Aug 70	Titan 3B-Agena D	16	110.95	89.67	151 - 365
1970-90	23 Oct 70	Titan 3B-Agena D	19	111.06	89.83	135 - 396
1971-05	21 Jan 71	Titan 3B-Agena D	19	110.86	90.09	139 - 418
1971-33	22 Apr 71	Titan 3B-Agena D	21	110.93	89.85	132 - 401
1971-70	12 Aug 71	Titan 3B-Agena D	22	111.00	90.13	137 - 424
1971-92	23 Oct 71	Titan 3B-Agena D	25	110.94	90.02	134 - 416
none	16 Feb 72	Titan 3B-Agena D		failed to orbit		
1972-16	17 Mar 72	Titan 3B-Agena D	25	110.98	89.91	131 - 409
none	20 May 72	Titan 3B-Agena D		failed to orbit		
1972-68	1 Sep 72	Titan 3B-Agena D	29	110.50	89.71	140 - 380
1972-103	21 Dec 72	Titan 3B-Agena D	33	110.45	89.68	139 - 378
1973-28	16 May 73	Titan 3B-Agena D	28	110.49	89.39	136 - 352
none	26 Jun 73	Titan 3B-Agena D		failed to orbit		
1973-68	27 Sep 73	Titan 3B-Agena D	32	110.48	89.67	131 - 385
1974-07	13 Feb 74	Titan 3B-Agena D	32	110.44	89.78	134 - 393
none	5 Jun 74	Titan 3B-Agena D		failed to orbit		
1974-42	6 Jun 74	Titan 3B-Agena D	47	110.49	89.81	136 - 394
1974-65	14 Aug 74	Titan 3B-Agena D	46	110.51	89.89	135 - 402
1975-32	18 Apr 75	Titan 3B-Agena D	48	110.54	89.26	134 - 401
1975-98	9 Oct 75	Titan 3B-Agena D	52	96.41	89.34	125 - 356
1976-27	22 Mar 76	Titan 3B-Agena D	57	96.40	89.25	125 - 347
1976-94	15 Sep 76	Titan 3B-Agena D	51	96.39	89.18	135 - 330

Table 3. Close-Look Satellites/contd.

Notes: 1. This table lists all satellites with the characteristics of close-look missions, to 31 December 1976.
2. Those launches marked with an asterisk carried ferret subsatellites which were ejected into separate orbits.
3. All launches were made from Vandenberg Air Force Base.

same local time, i.e., its precession was synchronised with the apparent yearly motion of the Sun. This meant that lighting conditions at the target areas would be the same each time the satellite passed overhead, which would make picking out changes to the scene much easier.

On the second flight the perigee was lowered by nearly 30 km to a height more typical of a close-look mission (the lower the altitude, the better the resolution), but the apogee was raised by a similar amount, so the period remained the same. Full operational status was attained with the third launch on 7 July 1972, and from this point onwards (with one exception, to be noted later) the flights all had perigees near 160 km and apogees near 265 km, but still retaining the Sun-synchronous inclination. Their orbital lifetimes quickly grew from two to four and then five months, with a steady average of two flights a year.

Big Bird launches have carried many subsatellites into orbit, starting with the second flight. Initially these were for ferret missions, following the end of the area survey programme in 1972, but two payloads for the Space Test Program have been orbited recently, along with several unidentified craft. In the future it is planned that UHF communications subsatellites will be carried to provide direct links from ground stations to SAC aircraft operating in polar regions [23].

For some years there have been reports of a fifth generation reconnaissance satellite to be built by TRW and known as Program 1010, which was to enter service in 1976 or 1977 [25]. It will be a further advancement in the state of the reconnaissance art by providing images in real-time. To accomplish this it is to carry television cameras, whose technology has advanced a long way since their rejection from WS-117L in 1957, and use data relay satellites. These are to be placed in synchronous orbit, and the reconnaissance vehicle's transmissions, instead of being sent to ground stations around the world, will go *via* the data relay satellites direct to the National Photographic Interpretation Center in Washington, D.C. [16]. A Big Bird was launched on 19 December 1976 into an unusually high orbit, from 247 km to 533 km. Four days later this was raised to 341 km to 535 km, more than double the altitude of the normal Big Bird orbit, and then three months later the satellite was again manoeuvred, resulting in a 264 km to 530 km orbit. This new type of orbit may indicate that it was the first test of a Program 1010 vehicle.

The Early Warning Satellites

In the late 1950's American projections of Soviet ICBM

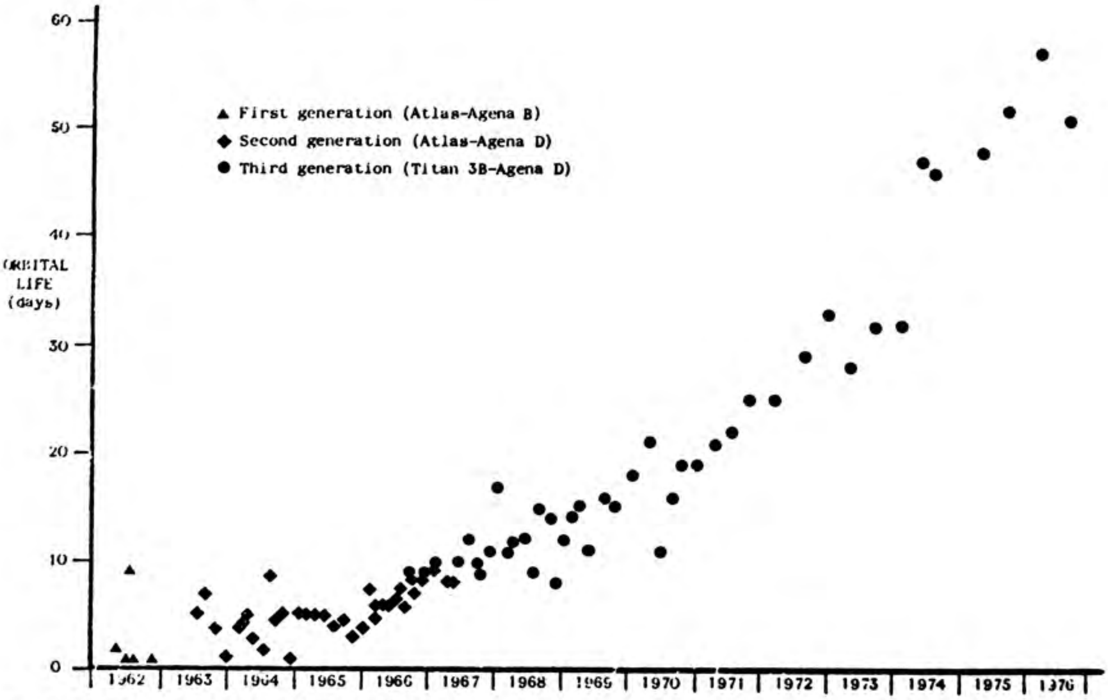


Fig. 5. Orbital lives of the 'close- look' satellite.

deployments indicated that by the early 1960's the USSR would have a substantial advantage over the USA, the so-called "Missile Gap." To counter this a crash programme of ICBM development was started, but it appeared that it would be some years before the balance could be tipped in favour of the United States. In the meantime, the main defence would be provided by manned bombers, which were far superior to their Russian counterparts. This policy had one drawback – it took some time to get the bomber force scrambled and in the air, and while they were still on the ground they were very vulnerable to attack. To make them into a credible defence force, a system had to be provided which would warn of a missile attack in enough time to get the bombers airborne. The Ballistic Missile Early Warning System (BMEWS), composed of three radar stations pointings towards the Soviet Union, was an attempt to provide this, but because they were line-of-sight radars they could only detect missiles after they rose above the horizon, several minutes after launch. In all, they were expected to give 15 minutes' warning, enough to get a fair proportion of aircraft in the air, but not long enough to get them all. The advent of Earth satellites brought a new possibility – if the ICBM launches could be detected from space in the first few seconds of flight, as much as 25 or 30 minutes' warning could be given, enough to get all of SAC's aircraft in the air. The Midas (for Missile Defence Alarm System) segment of WS-117L was set up to do just this.

The principle behind Midas was simple; when a rocket engine fires it produces an exhaust plume of very hot gases. Infra-red sensors on board satellites could detect these agains the background of the Earth, and so signal a launch in its early stages. A series of satellites in polar orbits with precisely controlled spacing could, it was hoped, provide a reliable warning system. Unfortunately, although the principle was straightforward, in practice there were many difficulties, and it was to be several years before the system could be considered operational [26].

The infra-red sensor for Midas, built by IT & T, had to be cooled to a low temperature in orbit, and designing such a system to work unattended in space posed many problems. Its weight, plus the weight of the complex orbit-spacing control system, pushed the total for the early models past the 2,000 kg mark, too much for the Atlas-Agena A to place in the planned orbit. As they were to test the concepts and hardware rather than be part of the operational network, it was decided to aim for low near-equatorial orbits, which were within the launcher's capabilities.

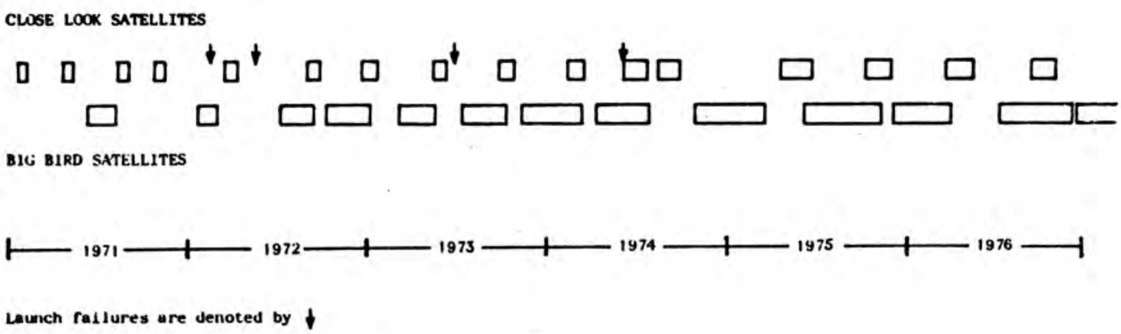


Fig. 6. Orbital histories of the 'close-look' and 'Big Bird' satellites,1971-76.

Table 4. Big Bird Satellites.

NAME	LAUNCH DATE (GMT)	LAUNCH VEHICLE	LIFE (days)	INCL. (deg)	PERIOD (min)	PERIGEE-APOGEE (kilometres)
1971-56	15 Jun 71	Titan 3D	52	96.41	89.38	184 - 300
*1972-02	20 Jan 72	Titan 3D	40	97.00	89.41	157 - 331
*1972-52	7 Jul 72	Titan 3D	68	96.88	88.77	174 - 251
*1972-79	10 Oct 72	Titan 3D	90	96.47	88.93	160 - 281
1973-14	9 Mar 73	Titan 3D	71	95.70	88.76	152 - 270
1973-46	13 Jul 73	Titan 3D	91	96.21	88.77	156 - 269
*1973-88	10 Nov 73	Titan 3D	123	96.93	88.85	159 - 275
*1974-20	10 Apr 74	Titan 3D	109	94.52	88.91	153 - 285
*1974-85	29 Oct 74	Titan 3D	141	96.69	88.86	162 - 271
*1975-51	8 Jun 75	Titan 3D	150	96.38	88.77	154 - 269
1975-114	4 Dec 75	Titan 3D	119	96.27	88.44	157 - 234
1976-65	8 Jul 76	Titan 3D	158	97.00	88.54	159 - 242
1976-125	19 Dec 76	Titan 3D		96.95	92.37	247 - 533

Notes: 1. This table lists all satellites with the characteristics of Big Bird missions, to 31 December 1976.
2. Those launches marked with an asterisk carried ferret subsatellites which were ejected into separate orbits.
3. All launches were made from Vandenberg Air Force Base.

Midas 1 was launched on 25 February 1960 (see Table 5), but the vehicle exploded during second stage separation [27]. Three months later Midas 2 successfully entered a good orbit, with a perigee of 484 km and an apogee of 511 km, giving it a period of 94.4 minutes. All seemed to be going well until the transmitter failed on the sixteenth orbit [28]. By this time the Discoverer programme had been experiencing many failures in its Agena stage, so the next Midas launch was postponed until they had been cured. When Discoverer flights were resumed later in the year two missions were dedicated to tests of sensors for the Midas programme. In the meantime, a change from batteries to solar panels [29] and a general weight reduction effort had cut the Midas payload to 1,600 kg. This, coupled with the use of the new Agena B stage, meant that flights in the operational type of orbit could now be attempted. Since these were to be near-polar, the launches were moved to Vandenberg Air Force Base, as range safety considerations precluded them from Cape Canaveral.

On 12 July 1961 Midas 3 achieved an orbit close to the planned one, almost circular (from 3,358 km to 3,534 km) with a period of 162 minutes. Midas 4 followed on 21 October, but although it was reported to have detected a Titan launch 90 seconds after liftoff on 26 October [30], it was soon clear that the performance of the sensors was not living up to expectations. The main problem was that they could not distinguish between rocket plumes and the reflection of the Sun off the tops of clouds, and signalled many false alarms. Meanwhile, the area survey satellites had shown that the "Missile Gap" did not exist, so the urgency of Midas was reduced [26]. These two factors led to the programme being cut back in mid-1962 to a research and development effort, renamed Program 461.

The Air Force had been investigating the radiation signatures of rocket exhausts during launches from Cape Canaveral since March 1960 using two U-2 aircraft [31], and this effort was stepped up in a search for sensors suitable for the early warning role. From these studies two programmes emerged; the first one was to use simplified spacecraft in random orbits, and was hoped to provide an interim capability. This was to be followed by a series of sophisticated spacecraft observing the Earth from synchronous orbit, built on the technology developed in the earlier programme. An idea of how badly astray the Midas programme had gone can be gained from testimony before Congress by Dr. Harold Brown, Director of Defense Research and Engineering, released on 16 June 1963. He said that of the $423 million spent on Midas up to that time, half had been wasted [32].

The first signs of success in the early warning programme came in President Johnson's report to Congress on aerospace activities in the year 1963. He stated that "two flights were conducted on which a number of in-space detections were made of both liquid-fuelled and solid-fuelled ICBM launches" [33], and he was obviously referring to the satellites launched on 9 May and 19 July, both of which were placed in polar orbits with periods of about 165 minutes, similar to Midas craft. No more launches were made for three years, and then two came in a space of seven weeks. It seems probable that they were to test a new technique that was then under development involving television cameras on board the satellites working in conjunction with the infra-red detectors. The idea was that when the infra-red detector signalled an alarm, the television camera, fitted with a telephoto lens, would focus on the region of interest, and its picture would be transmitted to Earth, where a person watching the scene could decide if this was a missile in flight or not [26].

Very little information about the success or otherwise of the interim programme has been made public, but the fact that development of the synchronous orbit system went ahead suggests that it achieved its goal. Early in 1966 requests for proposals were issued to industry under the code name of Program 266. At the end of the year, by which time it had been renamed Program 949, contracts were awarded to TRW (system contractor), Aerojet-General (for the infra-red sensors) and RCA (for the television system) [26]. The initial contracts were to develop and test sensor techniques, using spacecraft launched by Atlas-Agena D vehicles. If this was a success the go-ahead would be given for the operational programme.

The first synchronous orbit early warning satellite was launched from Cape Canaveral on 6 August 1968. Its orbit was inclined to the equator at an angle of 10°, so that it traced out a figure-eight pattern over the Earth. The aim of this was to improve coverage of the Soviet Union, whose main landmass lies well away from the equator. The orbit was not quite circular, with its apogee in the northern hemisphere, so the satellite dwelled over this region. It was stationed over western Russia, and eight months later it was joined by a second satellite. By arranging their orbits so that one was at its perigee when the other was at its apogee, there would always be one satellite over the northern hemisphere, in the best position to observe the Soviet Union. A third spacecraft was launched on 19 June 1970, but a booster failure left it stranded in its transfer orbit, so a back-up was launched in the following September, and was stationed

Table 5. Early Warning Satellites.

NAME	LAUNCH DATE (GMT)	LAUNCH VEHICLE	INCLINATION (degrees)	PERIOD (min)	PERIGEE-APOGEE (kilometres)
Midas 1	26 Feb 60	Atlas-Agena A	failed to orbit		
Midas 2	24 May 60	Atlas-Agena A	33.0	94.4	484 - 511
Midas 3	12 Jul 61	Atlas-Agena B	91.2	161.5	3358 - 3534
Midas 4	21 Oct 61	Atlas-Agena B	95.89	166.0	3496 - 3756
1962-κ	9 Apr 62	Atlas-Agena B	86.68	153.0	2814 - 3382
none	17 Dec 62	Atlas-Agena B	failed to orbit		
1963-14	9 May 63	Atlas-Agena B	87.42	166.5	3604 - 3680
none	12 Jun 63	Atlas-Agena B	failed to orbit		
1963-30	19 Jul 63	Atlas-Agena B	88.41	168.0	3670 - 3727
1966-77	19 Aug 66	Atlas-Agena D	90.07	167.6	3680 - 3700
1966-89	5 Oct 66	Atlas-Agena D	90.20	167.6	3682 - 3702
1968-63	6 Aug 68	Atlas-Agena D	9.9	1436	31,680 - 39,860
1969-36	13 Apr 69	Atlas-Agena D	9.9	1445	32,670 - 39,270
1970-46	19 Jun 70	Atlas-Agena D	28.21	588.9	178 - 33,685
1970-69	1 Sep 70	Atlas-Agena D	10.3	1441.9	31,947 - 39,855
1970-93	6 Nov 70	Titan 3C	7.8	1197.1	26,050 - 35,886
1971-39	5 May 71	Titan 3C	0.87	1434.0	35,651 - 35,840
none	4 Dec 71	Atlas-Agena D	failed to orbit		
1972-10	1 Mar 72	Titan 3C	0.2	1429.9	35,416 - 35,962
1972-101	20 Dec 72	Atlas-Agena D	9.7	1440.4	31,012 - 40,728
1973-13	6 Mar 73	Atlas-Agena D	0.2	1435.1	35,679 - 35,855
1973-40	12 Jun 73	Titan 3C	0.3	1435.9	35,777 - 35,786
1975-55	18 Jun 75	Titan 3C	9.0	1422	30,200 - 40,800
1975-118	14 Dec 75	Titan 3C	3.0	1436	35,671 - 35,785
1976-59	26 Jun 76	Titan 3C	0.5	1433.3	35,620 - 35,860

Notes:
1. This table lists all satellites with the characteristics of early warning missions, to 31 December 1976.
2. All launches into near-equatorial orbits were made from Cape Canaveral, and all launches into near-polar orbits were made from Vandenberg Air Force Base.

over Singapore [34]. This appears to be the satellite that was involved in the "laser blinding" controversy in 1975 [35].

The contractors for the operational system, known as Program 647, were the same as for the Atlas-Agena system, but the spacecraft itself was much bigger and required the Titan 3C to place it in orbit. The programme was divided into two phases; four Phase 1 spacecraft were to be built, three for flight and one for qualification and tests [36], and if they were successful the more advanced Phase 2 would follow. In addition to the missile early warning role, Program 647 vehicles carried sensors to detect nuclear explosions, and were to replace the Vela nuclear test detection satellites. Because of their dual function they are often referred to as integrated satellites.

The first Phase 1 spacecraft was launched on 6 November 1970, but a failure in the launch vehicle guidance system stopped it being placed in the planned orbit. It was possible, however, to adjust the orbit so that a limited amount of sensor testing could be performed, but as a consequence TRW was contracted to modify the non-flight spacecraft so it could be launched as a replacement should either of the next two flights fail. In fact, it was never needed; the other satellites were launched on 5 May 1971 and 1 March 1972, and performed so well that they were declared operational in 1972, and turned over to the Aerospace Defense Command, for whom the system was being developed. One was positioned over the Indian Ocean to monitor Soviet and Chinese missile tests and warn of attack by land-based missiles, and the other was positioned over Panama to warn of attack by submarine-launched missiles [36], and their circular non-inclined orbits meant that only one satellite was needed at each station. Ten years after the original target date, and in a form very different from what had then been envisaged, the United States now had an operational early warning satellite system.

In December 1971, a year after Program 949 appeared to have ended, an Atlas-Agena D was launched from Cape Canaveral. It had all the signs of an early warning mission, but since it veered off course and was destroyed by the Range Safety Officer [37], we cannot be certain. A year later, nearly ten months after the last Program 647 Phase 1 launch, another Atlas-Agena D left the pad, and placed its payload in synchronous orbit, as did a similar flight three months later. There were reports at the time that the infra-red sensors aboard Program 647 satellites were losing their sensitivity for unknown reasons, which suggests that the Atlas-Agena D flights may have been to test improvements to the system [36].

Deliveries to the USAF of Phase 2 spacecraft started in February 1973, and the first launch was made on 12 June. The satellite was positioned over the Indian Ocean, to supplement the one already there, and since then there have only been launches to replace satellites which showed degraded performance or failed. Thirteen Program 647 spacecraft have been procured [38], and five remain in storage to be launched as required.

Within the past few years, probably as a reflection of the programme's operational status, the veil of secrecy that covered it has been partially lifted. It has been referred to explicitly in budget requests (as the Defense Support Program), and details of the design of the spacecraft have been released. The central section of the satellite, where most of its equipment and instruments are housed, is a short cylinder, aligned in orbit with its axis pointing towards the Earth. The cylinder is 2.78 m in diameter and 2.91 m long, and it is covered with solar cells. The output from these is augmented by four solar panels mounted on the end facing away from the Earth. At the other end, looking down to the Earth, is the device which actually detects the missile launchings, an infra-red Schmidt telescope, 3.63 m long with an aperture of 0.91 m. The satellite's orientation in orbit is maintained by spinning about the cylinder's axis at 5 to 7 rpm; the telescope's axis is offset from this by about 7½°, producing a conical scanning pattern as the vehicle rotates. The infra-red sensor consists of an array 2,000 lead sulphide cells at the telescope's focal

Table 6. Ferret Satellites.

NAME	LAUNCH DATE (GMT)	LAUNCH VEHICLE	INCLINATION (degrees)	PERIOD (min)	PERIGEE-APOGEE (kilometres)
1962-σ	15 May 62	Thor-Agena B	82.33	94.02	305 - 634
1962-ω	18 Jun 62	Thor-Agena B	82.14	92.4	370 - 411
1962-αν	1 Sep 62	Thor-Agena B	82.82	94.42	300 - 669
1963-03	16 Jan 63	Thor-Agena D	81.89	94.66	459 - 533
1963-27	29 Jun 63	TAT-Agena B	82.3	94.84	484 - 536
1964-11	28 Feb 64	TAT-Agena D	82.03	94.74	479 - 520
1964-35	3 Jul 64	TAT-Agena D	82.09	94.94	501 - 529
1964-72	4 Nov 64	TAT-Agena D	82.00	95.05	512 - 526
1965-55	17 Jul 65	TAT-Agena D	70.18	94.46	471 - 512
1966-09	9 Feb 66	TAT-Agena D	82.09	94.83	508 - 512
1966-118	29 Dec 66	TAT-Agena D	75.03	94.41	486 - 496
1967-71	25 Jul 67	TAT-Agena D	75.03	94.30	458 - 513
1968-04	17 Jan 68	TAT-Agena D	75.16	94.53	450 - 546
1968-86	5 Oct 68	LTTAT-Agena D	74.97	94.55	483 - 511
1969-65	31 Jul 69	LTTAT-Agena D	75.02	94.67	462 - 541
1970-66	26 Aug 70	LTTAT-Agena D	74.99	94.51	484 - 504
1971-60	16 Jul 71	LTTAT-Agena D	75.00	94.59	488 - 508

Notes: 1. This table lists all satellites with the characteristics of ferret missions.
2. All launches were made from Vandenberg Air Force Base.

plane, and from synchronous orbit each cell views a region on the Earth less than 3 km across. The complete spacecraft weighs about 1,100 kg in orbit [38].

The Electronic Reconnaissance (Ferret) Satellites

If the area survey and close-look satellites are the "eyes" of reconnaissance, then the ferret satellites are the "ears." More correctly known as electronic reconnaissance vehicles, their mission is to pick up and record radio and radar transmissions while they are over foreign territory, for later replay back to ground stations at home for analysis. In this way it is possible to locate the enemy's aircraft and missile defence radars, and deduce a good deal about their characteristics and performance, to eavesdrop on military and governmental communications, including submarine-to-shore links, and it has even been suggested that telephone conversations can be monitored [39]. This knowledge gives a great insight into the offensive and defensive threats posed by the opposition, and to his strategy and future plans.

The United States started its electronic reconnaissance satellite programme at the beginning of the 1960's, but it has always been regarded by the Department of Defense as a very sensitive subject, and little information has been released about it. Although no ferret satellites have ever been officially identified as such, it is possible to pick them out by the type of orbit they use. For electronic reconnaissance, long life in a stable orbit is more important than the resolution attainable, so that the useful life of the satellite is determined by the reliability of its instruments rather than when it decays. Since the Spring of 1962 there has been a long series of spacecraft which have been placed in just this type of orbit, circular at an altitude of about 500 km, with a period of 94 to 95 minutes, from which they take four or five years to decay. There seem to be little doubt that these are ferret satellites.

Two types of vehicle have been used for ferret missions; the first is a large spacecraft, requiring its own booster, and the second is a small subsatellite, launched "piggy-back" with another, larger satellite. For this second type, once the pair of craft have been placed in orbit, the ferret,is ejected and fired into its own higher orbit. The first ferret launched by Thor-Agena B on 15 May 1962 (see Table 6), was one-of the large type, and it was followed a month later by another. From then onwards launches have occurred at increasing intervals, with a change to TAT-Agena D launcher in mid-1963 (presumably to accommodate a second generation spacecraft), and then to LTTAT-Agena D in the autumn of 1968 (presumably for a third generation). In the meantime, small ferret subsatellites were being regularly orbited with area survey and close-look launches, starting on 29 August 1963, see Table 7. It has been suggested that the two types of craft perform complementary roles, with the small ones carrying out search-and-find missions using low sensitivity equipment, and the large ones carrying out detailed examinations of selected targets using high sensitivity equipment [40]. If this is so, then it appears that when subsatellite launches were transferred to the Big Birds in January 1972, a new variant was introduced which combined the two functions in the same way that the Big Birds themselves combined the area survey and close-look functions for photographic reconnaissance. This would explain why the large type ferret launch of 16 July 1971 was the last of its kind, and from then on the job of electronic reconnaissance has been left to the subsatellites.

In December 1968 a subsatellite was ejected from an area survey flight into a new class of orbit, circular like the ferrets, but much higher, at 1,400 km altitude. Two months later this was repeated, but then the subsatellite launches reverted to their normal 500 km orbits. Philip Klass suggested in 1971 that these two flights might have been specifically designed to probe Soviet ABM radars, basing his reasoning on the fact that the Galosh system around Moscow reached operational status in the summer of 1969 [40]. Since he made this suggestion there have been three more flights at 1,400 km, and they can all be related to important periods in Soviet ABM developments, adding weight to his argument. The Strategic Arms Limitation Talks ABM Treaty came into force on 3 October 1972, and a week later a high orbit subsatellite was launched. Six months after this another was orbited, and it is reasonable to conclude that they were intended to police the agreement and check on possible violations. The most recent launch of this type came on 8 June 1975, at just the time when there was a great deal of activity at Sary Shagan, Russia's ABM test centre. Two new radar systems were undergoing tests then [41], and it is likely that the latest flight was planned to monitor them.

The current status of the electronic reconnaissance programme is not at all clear. It was reported in March 1970

that Hughes Aircraft was working on a new generation of heavy ferret vehicle under Program 711, to be launched by Titan 3 into a highly elliptical orbit. It was stated that the first launch was planned for late 1970 or early 1971, but no such flights have taken place, and the old type spacecraft orbited on 16 July 1971 was the last of the heavy ferrets. As has been suggested above, it is possible that their mission was carried out by the subsatellites launched with the Big Birds – indeed, it may be that plans for Program 711 were changed, and this is it – but there have been none of these since October 1974. It is hard to imagine that the electronic reconnaissance programme, which appears to have been successful in the past, should be suspended, but it will be some time before the new generation of ferrets, built under Program 980, come into service [42], so this does seem to be the case.

The US Navy's Ocean Surveillance Programme

In 1968 the US Navy initiated studies to explore the possibility of using surveillance radars in unmanned satellites to monitor the movements of ships at sea [43]. They stemmed from concern over the dramatic build-up in Soviet naval power since Admiral Gorshkov became its Commander in Chief in 1956, during which oceans and seas where the USN had once held undisputed power had become more and more the domain of ships from the Soviet Navy. The years 1967 and 1968 had been particularly impressive ones for the Russians; the following types of new vessel came into service in this period alone: Moskva class helicopter carriers, Kresta class guided missile cruisers, Charlie class submarines carrying the new SS-N-7 cruise missiles, Yankee class submarines carrying the new SS-N-6 ballistic missiles, and Victor class attack submarines [44]. In the past the USN had kept watch on the Soviet fleet with aircraft, but the increasing numbers of Soviet ships, and their vastly improved anti-aircraft armaments, led it to consider other surveillance methods, and satellites seemed an obvious choice.

The studies were to investigate the design and use of radars, both side-looking and forward-looking, and their aim was to develop a system which could measure the speed and direction of travel of ships. During the next five years several more contracts were issued to industrial teams for studies under Program 749, concentrating on the design of the satellite's sensors [45], but in 1973 it was announced that the Navy's programme of spaceborne ocean surveillance had been combined with a programme of very high altitude aircraft surveillance to form a "new and comprehensive aerospace surveillance programme" [46]. In retrospect, it would appear that the Navy's initial plans had not been fulfilled, for five years of study is a long time, especially when it is followed by a re-orientation, and it was to be another three years before the first spacecraft was actually launched. U-2 aircraft, in a modified version known as EP-X, had been flying ocean surveillance sensors since February 1973, and it was confirmed that they were to be the aircraft segment of the new programme, which was given the code name Whitecloud [47, 48]. Later in the year it was also revealed that the Navy had been using imagery from USAF reconnaissance satellites since 1971, as a further aid to its studies [21].

Table 7. Ferret Subsatellites.

NAME	LAUNCH DATE (GMT)	LAUNCH VEHICLE	INCLINATION (degrees)	PERIOD (min)	PERIGEE-APOGEE (kilometres)
1963-35	29 Aug 63	Thor-Agena D	81.89	92.07	310 - 431
1963-42	29 Oct 63	TAT-Agena D	89.99	93.35	285 - 585
1963-55	21 Dec 63	TAT-Agena D	64.52	91.68	321 - 388
1964-36	6 Jul 64	Atlas-Agena D	92.97	91.2	297 - 377
1964-68	23 Oct 64	Atlas-Agena D	95.50	91.14	323 - 336
1965-31	28 Apr 65	Atlas-Agena D	95.26	95.16	490 - 559
1965-50	25 Jun 65	Atlas-Agena D	107.65	94.68	496 - 510
1965-62	3 Aug 65	Atlas-Agena D	107.36	94.78	501 - 515
1966-39	14 May 66	Atlas-Agena D	109.94	95.39	517 - 559
1966-74	16 Aug 66	Atlas-Agena D	93.17	94.99	510 - 524
1966-83	16 Sep 66	Atlas-Agena D	94.06	94.25	460 - 501
1967-43	9 May 67	LTTAT-Agena D	85.10	98.38	555 - 809
1967-62	16 Jun 67	LTTAT-Agena D	80.20	94.81	501 - 517
1967-109	2 Nov 67	LTTAT-Agena D	81.68	94.41	455 - 524
1968-08	24 Jan 68	LTTAT-Agena D	81.65	94.75	473 - 542
1968-20	14 Mar 68	LTTAT-Agena D	83.09	94.66	481 - 522
1968-52	20 Jun 68	LTTAT-Agena D	85.18	94.15	437 - 519
1968-78	18 Sep 68	LTTAT-Agena D	83.22	94.75	500 - 514
1968-112	12 Dec 68	LTTAT-Agena D	80.33	114.45	1391 - 1468
1969-10	5 Feb 69	LTTAT-Agena D	80.41	114.22	1396 - 1441
1969-26	19 Mar 69	LTTAT-Agena D	83.08	94.82	504 - 513
1969-41	2 May 69	LTTAT-Agena D	65.71	93.37	401 - 473
1969-79	22 Sep 69	LTTAT-Agena D	85.16	94.51	490 - 496
1970-16	4 Mar 70	LTTAT-Agena D	88.14	94.16	442 - 514
1970-40	20 May 70	LTTAT-Agena D	83.12	94.59	491 - 503
1970-98	18 Nov 70	LTTAT-Agena D	83.18	94.63	487 - 511
1971-76	10 Sep 71	LTTAT-Agena D	75.07	94.60	492 - 507
1972-02	20 Jan 72	Titan 3D	96.59	94.86	472 - 549
1972-52	7 Jul 72	Titan 3D	96.15	94.66	497 - 504
1972-79	10 Oct 72	Titan 3D	95.62	114.79	1423 - 1469
1973-88	10 Nov 73	Titan 3D	96.33 96.93	94.59 114.64	486 - 508 1419 - 1458
1974-20	10 Apr 74	Titan 3D	94.00	95.01	503 - 531
1974-85	29 Oct 74	Titan 3D	96.06	95.22	520 - 535
1975-51	8 Jun 75	Titan 3D	95.09	113.68	1389 - 1401

Notes: 1. This table lists all subsatellites with the characteristics of ferret missions.
2. These subsatellites result from the launches listed in Tables 2, 3 and 4 which are marked with an asterisk.
3. All launches were made from Vandenberg Air Force Base.

The years of research finally reached fruition on 30 April 1976 with the launch of the first ocean surveillance satellite. It was placed in 1,092 km to 1,128 km orbit, inclined at 63°, by an Atlas rocket. The Naval Research Laboratory had designed and built the spacecraft, with the assistance of Fairchild Industries [49], and with the range of sensors it is reported to have it appears to be a very sophisticated vehicle. It is believed to carry millimetre-wave radar, with the capability of tracking surface ships in all weather conditions, radio-frequency antennae for listening in on shipboard radar and communications, and passive infra-red detectors [50], possibly to plot the courses of submerged nuclear submarines, which leave behind them a wake of water that has been used to cool their reactors and is warmer than the surrounding sea, or to track low-flying missiles. Once in orbit it released three small subsatellites into similar orbits to its own (see Table 8), and each of these is reported to carry its own sensors. Their data is transmitted to the parent satellite, where it undergoes preliminary processing before being re-transmitted to Earth [51].

Table 8. Ocean Surveillance Satellites

Spacecraft	Inclination (degrees)	Period (min)	Perigee-Apogee (kilometres)
Main satellite	63.46	107.47	1092 -1128
Subsatellite 1	63.44	107.49	1093-1129
Subsatellite 2	63.43	107.50	1093-1130
Subsatellite 3	63.45	107.49	1083-1139

Notes:
1. This table lists the orbital parameters of the ocean surveillance satellite and of the three subsatellites it released in orbit.
2. All four elements were orbited as a single vehicle on 30 April 1976 by Atlas booster from Vandenberg Air Force Base.

The launch of 30 April 1976 is the only ocean surveillance satellite to date, but the indications are that many more will follow as the Navy increases its reliance on spaceborne sensors to keep watch on the high seas. Although the Navy's first reconnaissance satellite was launched 14 years after the Air Force's first, the level of sophistication and complexity that is claimed for it certainly matches that of its USAF contemporaries.

Sensors – Types and Performance

So far I have considered the types of satellites used for reconnaissance and surveillance, but now I shall turn to the sensors they carry for their missions. Just what these satellites can detect is a well kept secret – no reconnaissance satellite picture has ever been released, and it is unlikely that any will be in the foreseeable future – but it is possible to estimate the performance that the sensors should be able to achieve by examining the physical laws they must obey and the performance of civilian systems with similar levels of technology.

All the information that reaches a satellite from the Earth comes in the form of electromagnetic radiation. Although the atmosphere may seem transparent to us, it is in fact opaque to most wavelengths, with only two "windows" through which radiation can pass freely. One "window" covers wavelengths in the range from 0.3μ up to about 10μ, which includes some near ultra-violet, visible light, near infra-red and some far infra-red, and the other from 3 cm to 3 m, which includes radio and radar in the US military bands A through I. Any satellite that is to observe events on Earth must use sensors which operate at these wavelengths.

Cameras operating in the visible portion of the spectrum were the first type of sensor to be used for reconnaissance, and they are still the most common today. The reasons for this are simple; camera design is a well-developed art, they give the best resolution of any wavelength range, and they are the easiest for humans to interpret and understand. The limiting resolution on the ground that a satellite camera system can achieve can be considered as composed of two components – the limiting resolution of the atmosphere and the limiting resolution of the camera itself. These two interact in a complex way to form the achievable resolution, but a way of combining them has been suggested by Amrom Katz [52]. If all resolutions are expressed in terms of the smallest object discernable on the ground, then the achievable limit is simply the sum of the component limits (it should be stressed here that all the calculations which follow are approximate – to be more accurate would require knowledge of a great many details of the satellite's design, details which are highly classified). This rule has an important consequence; the achievable resolution will always be worse that the worst of the component resolutions, so that however good a satellite's design may be, its resolution will always be at least as bad as that due to the atmosphere. It also means that as the camera's resolution is improved more and more, the law of diminishing returns will cut in – the better the system gets, the less effect will further improvements have.

It is generally considered that the atmosphere's limiting resolution is about 10 cm [53], which is independent of the satellite's altitude. All other things being equal, a camera's resolution is dependent on the ratio of its altitude to its focal length, a parameter known as the scale number. Now many details, including achievable resolution, focal length and altitude, have been published for some civilian satellite camera systems. If we can find details for a system of comparable technology to a given reconnaissance satellite, and we know the reconnaissance satellite's focal length and altitude, it is a simple matter to estimate its achievable resolution. Consider the S190A Multispectral Photographic Camera carried on the Skylab missions; it had a focal length of 15.24 cm, and at an altitude of 436 km its achievable ground resolution was 24 m [54]. This gives a scale number of 2,860,000 and as the atmospheric resolution is so small compared with the achievable resolution, a camera resolution of 24 m. Big Bird has been reported to carry a camera with a focal length of "more than eight feet" [17], so taking a value of 2.5 m and an altitude of 160 km, a typical perigee height, gives a scale number of 64,000, and assuming its level of technology is similar to Skylab's gives a camera resolution of 55 cm, and thus an achievable resolution of about two thirds of a metre.

As was mentioned earlier, the photographic system carried by the Lunar Orbiter spacecraft appears to be very closely related to that carried on the early Samos area survey satellites. Its focal length was 61 cm, and operating at an altitude of 46 km it had a resolution of 1 m [55]. This means a scale number of 75,400 and a camera resolution of 1 m, there being no atmospheric effects on the Moon. The early Samos vehicles were claimed to have cameras with focal lengths "as large as 40 inches" [13], so taking a value of 1 m and an altitude of 180 km, typical of the perigees they used, gives a scale number of 180,000 and thus a camera resolution of 2.4 m, so we can estimate the achievable resolution to be about two and a half metres.

It is interesting to compare these two estimates with some of the claims that have been made for reconnaissance satellite capabilities. Philip Klass stated that early Samos satellites should have been able to resolve objects 20 feet across from 300 miles [11]. This scales to 2.3 m from 180 km, in very good agreement with the figure computed here. One would expect the cameras carried by U-2 aircraft, which

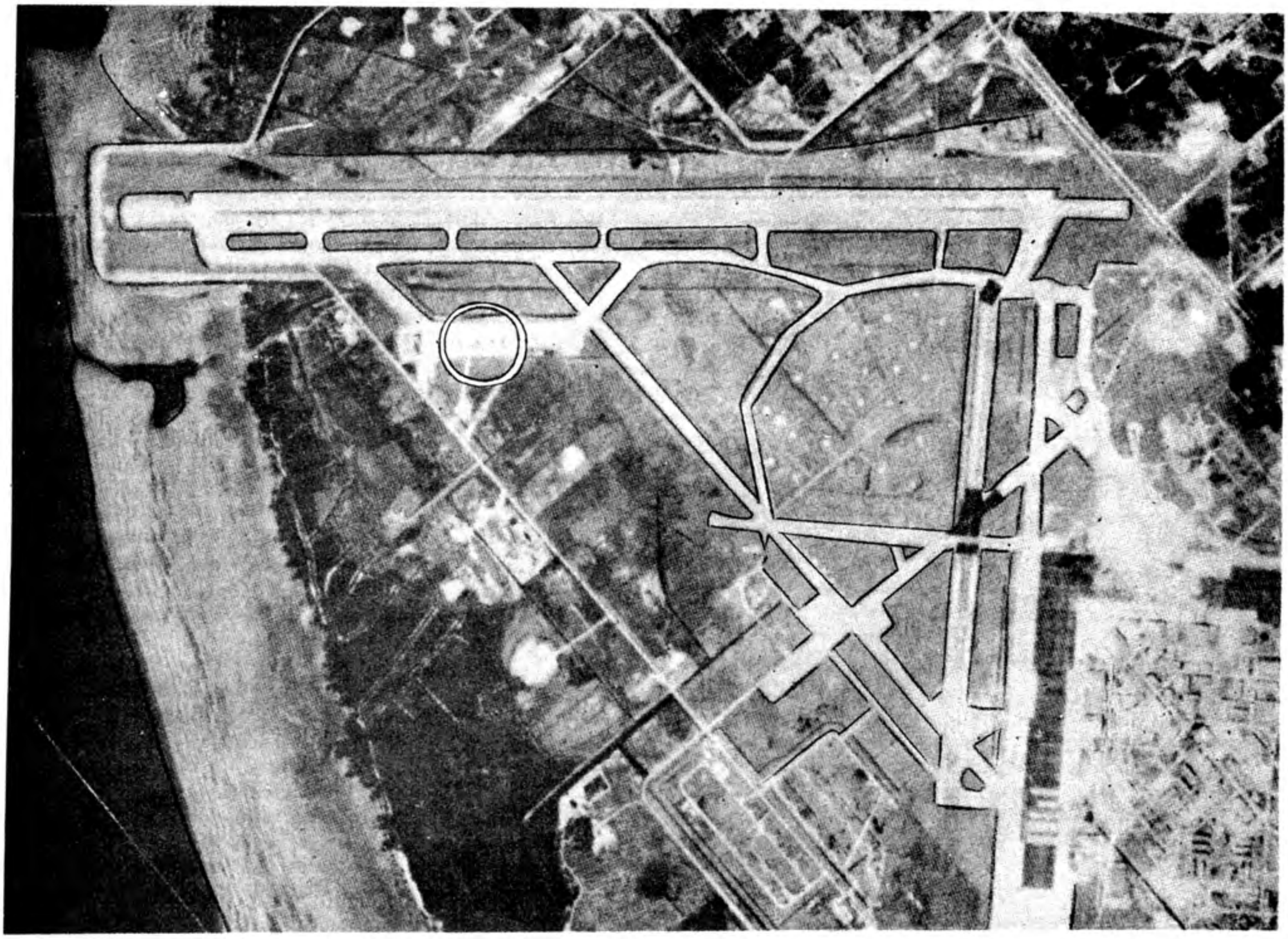


Fig. 7. One of the most revealing space photos of military interest yet released by the United States. Picture is an enlargement of a larger photograph obtained from the Skylab space station showing MacDill Air Force Base. Within the circle can be seen four aircraft parked off the main runway. All photographs obtained by U.S. reconnaissance satellites are classified and this picture gives only a small indication of the resolution that can be obtained [20].

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were contemporaries of the early Samos vehicles, to have similar or slightly better performance (the weight considerations would have been less constraining in an aircraft than a spacecraft). After the Gary Powers incident President Eisenhower showed photos taken from a U-2 flying 21 km over San Diego. They clearly showed the 10 cm wide lines painted on a car park [56]. This would become a resolution of 85 cm from 180 km altitude, somewhat better than our Samos estimate, but considering the degredation due to the area survey satellites' radio transmission system, and that light coloured lines on a dark asphalt background would make an ideal photographic target, the figures are quite compatible.

The dimensions quoted for the smallest objects that can be resolved generally refer to objects whose length and width are of the same sort of order. It is well known, however, that an object which is several orders of magnitude longer than it is wide can be resolved when its width is well below the limiting resolution. There is a good example of this in [52]; a photograph taken from a Viking rocket has a computed resolution of 150 m, and yet it is possible to pick out a railway line, which can be no more than one twentieth of this wide, even including cuttings and embankments. This would imply that it may be possible to pick out extremely elongated objects from Big Birds which are as small as two or three centimetres wide. An example of this would be the high voltage cables of the National Grid, but the claim [57] that individual telephone cables (diameter 3 mm) can be detected does seem to be rather optimistic. Certainly the report [58] that the buttons on a man's shirt can be resolved should be regarded with considerable reservations.

Resolution, however, is not the only consideration when designing a sensor for reconnaissance. The main concern is to maximise the amount of information that can be extracted from the data returned, and one aid to this is infra-red photography. For wavelengths up to about 1μ photographic emulsions have been developed which produce infra-red "pictures" when they are used in conventional cameras. The main advantage that they have over visible light imagery is that surfaces which may be indistinguishable in visible light, like for example a patch of grass and a camouflaged missile silo cover, look quite different in infra-red, because of their different reflection characteristics. This capability to penetrate camouflage was first exploited in aerial reconnaissance during the Second World War, and since then it has become a well established technique. Unfortunately the resolution obtainable with infra-red photography is not nearly as good as visible light photography – Skylab's S190A camera's infra-red resolution was 68 m compared to 24 m in the visible band – so simultaneous photography in both regions of the spectrum came into use, taking advantage of the

good features of each while minimising the effects of the bad ones. This in turn led to multi-spectral photography, where images are made in several portions of the visible and infra-red spectrum simultaneously. By careful choice of the film/filter combinations, each image can be made to show a different feature of the target, and comparisons between the images can yield still more to the skilled photo-interpreter.

When the new generation of close-look satellites came into service in 1966 they carried multi-spectral cameras, but it was not until 1969 that a similar instrument was flown on a civilian mission, as experiment SO-65 on Apollo 9. This consisted of four cameras rigidly mounted on a frame and boresighted to view exactly the same area of the Earth. Camera AA used an orange filter in combination with film sensitive to wavelengths between 0.51μ and 0.91μ, giving good differentiation between natural and man-made objects by measuring plant reflectance. Camera BB used a green filter and film sensitive to 0.48μ to 0.62μ, which penetrated shallow water to show the structure of river beds and coastal seabeds. Camera CC used a very dark red filter and film sensitive to 0.7μ to 0.9μ, which showed plant health, disease and insect infestation. Camera DD used a red filter and film sensitive to 0.59μ to 0.72μ, which showed terrestrial structures in a form suitable for mapping and land usage studies [59]. obviously, the ability to obtain images which can show such particular features would be of great use to reconnaissance analysts.

At wavelengths beyond about 1μ it is not possible to use photographic emulsions, and sensors composed of detector elements which give an electrical output dependent on the level of illumination must be used. The output signal can be utilised to build up a photograph-like image, but the resolution attainable is considerably lower than with conventional photography. This type of sensor does have one great advantage though; because the radiation they detect is thermal rather than reflected solar radiation, they operate just as well at nighttime as daytime. A typical example is the line-scanning radiometer carried by the Defense Meteorological Satellite Program (DMSP) vehicles. It has two channels which operate in the 0.4μ to 1.1μ range, using silicon diode sensing elements, and two in the 8μ to 13μ band, using mercury cadmium telluride sensors. From an altitude of 750 km the maximum resolution in the shorter wavelength band 630 m, and maximum in the longer band is 670 m [60]. Infra-red scanners were introduced into satellite reconnaissance with the third generation of area survey satellites in 1966; at the kind of altitude they used, the resolution of the DMSP scanners would be 150 m and 160 m, certainly good enough to be of use in reconnaissance.

Sensors operating at radiation wavelengths produced at the sort of temperatures experienced on Earth, such as DMSP's mercury cadium telluride detectors, do have one major drawback – they require cryogenic cooling, in DMSP's case to 100K. This, of course, increases the spacecraft's complexity considerably and makes the reliability necessary for long life hard to attain. The Program 647 early warning satellites bypass this problem by making use of the fact that as the temperature of the emitter increases, the wavelength of its radiation decreases, and detectors sensitive to the wavelengths emitted by the hot gases of a rocket exhaust have a much higher working temperature. The early warning satellites use lead sulphide cells which have a peak response at 2.7μ and operate at 193K and this comparatively high temperature means that they can use passive cooling [38]. It does mean, however, that they can only detect missiles while their motors are firing, and once burnout is reached and the short wavelength emissions stop the ability to track them is lost.

Sensors which use the long wavelength atmospheric "window" can be divided into two types, passive and active. Passive sensors do not emit radio or radar signals; they simply listen to whatever they can pick up, record it and then when they are over home territory re-transmit it to a receiving station for processing and analysis on the ground. This type of sensor has been in use on the ferret satellites since 1962, but like all else to do with this programme, their performance is shrouded in secrecy.

Active sensors are those which transmit their own signals and use the reflections to determine the presence of other objects. For reconnaissance and surveillance purposes these are mostly confined to radars operating at the middle of the wavelength range, in what used to be called the L-band but is now referred to as the D-band by United States military agencies (it covers the range of wavelengths from 15 cm to 30 cm, that is frequencies from 1 GHz to 2 GHz). Radars such as these have one great advantage – their performance is unaffected by weather conditions. However, they do have one great disadvantage – to give anything like reasonable resolution requires very large antennae. As an example of this, the latest ground-based radar used to detect and track re-entry vehicles and satellites, the USAF's Cobra Dane at Shemya in the Aleutians, also operates in the D-band but its phased array antenna is 29 m in diameter [61]. Obviously, such a size is out of the question for spaceborne applications with present-day technology, and so active radars have found very little application in satellite reconnaissance.

This situation has changed recently with the development of a technique known as synthetic aperture side-looking radar. For this the vehicle transmits radar pulses in a narrow fan at right angles to the direction of flight. As the radar beam sweeps through the fan, the reflected signal is converted into a fine light beam which is scanned across a photographic film. The forward motion of the vehicle, and thus the radar fan, is translated into a motion of the photographic film, so that successive scans build up a picture in much the same way as a television image is built up from a set of lines. The vehicle's forward movement makes the antenna "appear" much larger to objects on the ground, and as the resolution of a radar is proportional to its antenna size, a dramatic improvement in performance over conventional radars can be realised. When NASA's Seasat is launched in May 1978 it will carry a synthetic aperture side-looking radar operating at 1.3 GHz which will have a resolution of 25 m [35]. It has been suggested that the Big Birds carry this type of radar, and although a resolution of 25 m is far poorer than they achieve with their optical devices, the capability to produce images in all weather conditions and at any time of day would be of great value in reconnaissance. The US Navy had also planned to use a side-looking radar in its ocean surveillance satellite, but studies showed that the pitching and rolling movements of a ship at sea would destroy the phase relationships necessary for the technique to work, and so a conventional forward-looking radar is used, although still operating in the D-band [62].

Future Developments

Since the days of the Discoverer programme satellite reconnaissance has evolved from an experimental technique to a reliable, regular, highly sophisticated technology. This is not to say, however, that current capabilities cannot be improved upon, and several programmes are being pursued with this aim.

For some years the main effort in this field has been to expand the missile tracking capabilities of the early warning satellites to include the mid-course coast phase as well as the boost phase. This requires sensors operating in the long wavelength infra-red range (8μ to 14μ), which in turn requires the use of cryogenic cooling. Today's satellites were designed at a time when the most important consideration was to provide a simple and reliable system, so the decision

Table 9. Summary of Launches by Programme and by Year.

Programme	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
Discoverer	8	11	17	2															38
Area Survey		1	4	18	17	14	14	9	9	8	6	4	3	2					109
Close-Look				6	4	10	9	15	10	8	6	5	4	5	3	4	2	2	93
Big Bird													1	3	3	2	2	2	13
Early Warning		2	2	2	3			2		1	1	3	2	2	2		2	1	25
Ferret				3	2	3	1	2	1	2	1	1	1						17
Ocean Survey																		1	1
Total	8	14	23	31	26	27	24	28	20	19	14	13	11	12	8	6	6	6	296

was made to use short wavelength sensors, but now the technology of space vehicle design has reached a stage where long wavelength infra-red sensors are becoming a practical proposition for long-term space applications.

As far back as 1969 research was under way in this field [63], and in June 1971 a sensor of this type was flown as Space Test Program payload P70-1 to provide background measurements in support of this work [64, 65]. Following on is the Satellite Infra-Red Experiment (SIRE) which aims to demonstrate the ability of long wavelength sensors to detect space vehicles against the cool space background, culminating in a subsatellite launch in 1980 or 1981. Hughes Aircraft has been contracted to build the sensor and its associated cooling system, and the spacecraft contractor is to be chosen soon [66].

The SIRE payload will be part of a package of DoD experiments in its Space Test Program that mark the first military use of the Space Shuttle. Another payload planned for this mission is from the Teal Ruby programme to investigate the possibility of detecting aircraft from surveillance satellites. Jet engines produce relatively intense infra-red radiation, but discriminating it from the background of the Earth, with all its other radiations, presents considerable difficulties. The key to the solution lies in a new type of sensor called a mosaic focal plane array. A mosaic array is a two-dimensional array of batch-processed detectors mounted integrally with charge coupled devices on a single chip, with as many as several thousand on one chip. By integrating the charge coupled devices, which amplify and process the detector signals, on the same chip as the detectors most of the costly hand-wired interconnections required on an array of the type used by the Program 647 satellites can be replaced by thin film connections, greatly reducing the electrical heating produced during operation, and so allowing smaller cooling units to be used. The high detector densities and anticipated low costs mean that focal plane arrays of hundreds of thousands of channels can be constructed – Teal Ruby's will use a quarter of a million [67] – compared to the 2,000 used in today's satellites. They will be operated in a "staring" mode, with each detector observing the same region continuously and the signal processing logic programmed to respond to changes in illumination levels [68, 69].

Looking further into the future, the Air Force is developing in its High Altitude Large Optics (HALO) programme a multiple threat warning and observation satellite as a replacement for current systems in the 1990's. As it is currently envisaged, a HALO vehicle would be assembled from components orbited in six Space Shuttle flights, and would include adaptive optics using a structure up to 30 m in diameter, mosaic infra-red arrays and high resolution television [70, 71].

Satellite Reconnaissance – The Biggest Payoff of the Space Programme?

Table 9 gives a year-by-year and programme-by-programme breakdown of reconnaissance satellite launches, and it shows that by the end of 1976 there had been 296. Of these 262 succeeded in placing their payloads in orbit, which amounts to 43% of all United States launches to orbit and beyond. This represents a considerable investment in men and resources, and the question naturally arises, has it been worth it? The answer seems to be a very definite "yes," although it is hard to substantiate it in detail because the benefits of satellite reconnaissance are only apparent to the public in indirect ways.

A military organisation must arm itself to counter all the attacks that it percieves an enemy might be able to launch. If it knows in detail just what weapons the enemy has, how they are deployed and what their capabilities are, it can do this with a reasonable level of funding and a good degree of confidence, but if its knowledge is sketchy or incomplete, then it is obliged to develop a whole range of weapons "just in case." This inflates military budgets and, by the interaction of each side trying to match the other, sends the arms race spiralling up. The role of reconnaissance satellites has been to provide this knowledge, and the benefits they have brought are measured in terms of the weapons projects which have not been pursued, but which in the absence of this knowledge would have fallen into the "just in case" category, and would have been pushed through to deployment.

A clue to the scale of these savings was given in a briefing by President Johnson on 16 March 1967. While commenting on the amount of money spent on the space programme, he said "....and if nothing else has come out of it except the knowledge we've gained from space photography, it would be worth tens times what the whole programme cost." [72]. By 30 June 1967 the United States had spent $38.70 billion on its space programme [73, 74], and so the President's figure would imply that the savings were of the order of several hundred billion dollars. Of that $38.70 billion, $10.79 billion had been spent by the DoD, so the cost of the whole reconnaissance satellite effort must have been less than $10 billion, making it not only a very beneficial programme but also a very cost-effective one. There seems no reason to believe that the utility of reconnaissance satellites has been any less since 1967, so extrapolating President Johnson's figure suggests that by now the savings must be in the region of a staggering thousand billion dollars.

Sources of Data Used in Compiling the Tables

The data concerning the successful launches was taken from the RAE's *Table of Earth Satellites* (Volume 1: 1957-

1968, Volume 2: 1969-1973, and Volume 3, Parts 1, 2 & 3: 1974-1976), although in a few cases the identification of the launch vehicle was taken from *TRW Space Log* (published by the Public Relations staff of TRW Systems), the *United Nations Public Registry*, or the references cited below. Data concerning the launch failures was drawn from *TRW Space Log, Table of Earth Satellite and Space Vehicle Failures, 1957-1973* (published privately by J. A. Pilkington, 1974), and NASA's annual compilation *Astronautics and Aeronautics.*

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SHUTTLE VIBRATION TESTS

Ground vibration tests of the Space Shuttle began last May in a tall test tower at the Marshall Space Flight Center in Huntsville, Alabama. The Orbiter and its Expendable Tank were 'soft-mounted' inside the stand using a system of air bags and cables to suspend the vehicles from a large overhead truss installed like a crossbeam between two test stand walls.

In the tests a computerized Shuttle Model Test and Analysis System (SMTAS) provides required vibrational cycles and force inputs and acquires response data from the vehicle. The term 'vibration' may be misleading. It is not in any way a shake test to find the strength of the vehicle. Engineers simply apply vibrations to its exterior with exciters powered by amplifiers similar to those found on home stereo sets. Sensors record the characteristics of the vibrations as they pass from one area of the vehicle to another.

The information allows engineers to verify the system design and mathematical models that predict how the Shuttle's control system will react to the much more severe vibrations expected during launch and flight into orbit.

Ground vibration tests with the 'Enterprise' prototype will continue for most of the year with pauses only to change the test configuration of the Space Shuttle.

First flight into orbit from Cape Canaveral by vehicle OFT-1 is now scheduled for mid-1979. The test crew will be John W. Young, commander, and Robert L. Crippen, pilot.

QUO VADIS?

By H. E. Ross

To frame a philosophy capable of coping with men intoxicated with the prospect of almost unlimited power and also with the apathy of the powerless is the most pressing task of our time.

Bertrand Russell

Introduction

Cosmonautics is, by any standard, megalomania on the grandest possible scale. Right from the start its pioneers prophesised that the human race would establish Bases and Colonies throughout the Solar System and go on to cross the immensity of deep Space to inherit the Stars. Today, with great technological achievements already behind us – manned landings on our Moon and robot probings to distant planets accomplished – it seems likely that a great Cosmic destiny does, in fact, await us. Indeed, though for a very long time it was argued that Man had to choose between "All or Nothing?" it is now apparent that Nature had really left us no alternative in the matter when we choose All. Knowledge is power, and Man must have power over Nature in order to improve his lot and secure his future.

Ideals and Motives

Avoidance of a lethal cataclysm involving our Sun is, for instance, one cogent reason for the crossing of Space by Man himself, instead of relying wholly upon robot agents to collect knowledge for us. Such a catastrophic event is probably of little short-term concern; Man will explore Space himself, if for no other reason than because it is his nature to desire *personal experience*, which our robot agents, however sophisticated and competent they may become cannot provide. Self-Sufficient Colonization to support exploration and scientific research effectively is made necessary, at any rate in the long term within the Solar System, by the exceedingly lengthy transit times between the distant planetary bodies and the consequent need to avoid the inconvenience and wastefulness of endless interplanet transportation.... Incidentally, these long transit times are a factor opposing the evolution of a large-scale interplanetary trading network such as is sometimes envisaged.

Despite these and other portents of our Cosmic future we have, strangely enough, given little thought to what repercussions there may be on us as individuals and on human Society resulting from our acquisition of ability to live away from kindly Mother Earth, under, in most cases, extremely antagonistic environmental conditions. Nowhere else in the Solar System – not even on Mars or Venus – can Man live freely on the surface; unless, eventually, it becomes possible for him to engage in planetary engineering and change – or actually fabricate – other worlds to suit himself, or perhaps to breed specialised intelligent beings adapted to the particular conditions of other worlds. Or, indeed, to up-grade himself into *Homo superior*.... For is there not in Man a subliminal craving to be something more than just the precocious super-ape *Homo-sapiens?* Perhaps natural evolution will someday do that for us anyway for otherwise, only when it becomes possible to cross to the stars will we stand a chance of finding another world comparable to our own in physical suitability. Even should this be the result of interstellar voyaging, we must bear in mind that another world substantially like our own Earth might have bred or be in process of evolving intelligent beings similar to ourselves, likely to resent and to resist any attempts on our part in the matter of planet-sharing or complete take-over....

On the Building of Stable Social Societies in Space

In my view only the dire necessity to avoid the extinction of the human race would *permit* (I deliberately avoid the term *'justify'*) a take-over in such circumstances, for it seems to me that each intelligent species must award itself the ultimate 'right' to fight for survival. Fortunately, a philosophical, ethical and downright practical problem of this kind is, except for the possible advent here of Extraterrestrial Beings, far-off in time and distance. On the other hand, urgent considerations relevant to extraterrestrial expansion are already emerging as the result of various technological hardware studies of ET Colonies, and – imminently – Space Factories. Let us, whilst there is time, consider some of the social aspects.

Responsible Citizenship

It would seem true to say that conquest of all the get-at-able part of the Cosmos would be a technological push-over if *people* were not involved, people with characters ranging from spiritual and lay saints to incarnate demons, those who would wholeheartedly cooperate in good responsible citizenship and those capable of fouling and destroying everything they contact; and frighteningly irresponsible people who would impose an intolerable burden on an embattled ET Community.

As Dr. Alexis Carrel pointed out in his book *Man, The Unknown:*

"Everybody is interested in things that increase wealth and comfort, but no one understands that the structural, functional, and mental quality of each individual has to be improved."

In the particular case of a precariously emerging ET Community, which in needfully strict social discipline may be compared to the traditional ship at sea, highly responsible, non-mutinous, citizenship is obviously imperative. On the other hand, the general run of workers in an ET Colony, or the Space Factories now being seriously considered, must never be allowed to become simply the ant-slaves of their bread-winning occupations. That happened on Earth: It should not happen again anywhere.

Though, clearly, we cannot hope to eradicate all the wilful evil and sheer cussedness in ourselves, except by later-time genetic engineering, we can suppress much of the bad through early and scrupulous schooling in morals and citizenship; i.e. with a teaching not based on, and left to, confusing religious tenets alone, where right things may be advocated for the wrong reasons, but springing from sound scientific secular appraisals. For instance, clear distinction must be made between the Theology and the Sociology of the Religions, to identify what would still be accounted right for humankind, even without a God. History has shown time and time again that most people can be trained to be good or to be bad: unfortunately, we at the present time do not care enough *what* people are. Today the bad have never had it so good.

Mark Twain was right when he said: *"Training is everything.... cauliflower is nothing but cabbage with a college education"*.... The question then remains as to what to do about the residue of people found to be incurably bad. Bearing in mind that a Space Colony, in particular, will probably not be able to afford the blighting luxury of supporting incorrigible villians and junkies, the solution is likely to be severe, including execution. In any case, we would do well to bear in mind John Ruskin's comment: *"Make your educational laws strict and your criminal ones*

may be gentle; but leave youth its liberty and you will have to dig dungeons for age." Certainly, the Permissive Society, where benign Authority has abdicated and everything goes unchallenged, is unacceptable. Nowadays far too much time is spent pandering to the decadent extravaganzas of cohorts of raucously jungle-minded weirdie juveniles. Moreover, children have become people everywhere. Certainly, for cosmonautical conservation reasons alone, a Consumer Society, which is inherently wasteful, rapacious, reckless, unstable, dishonest, and altogether unscientific, is an inadmissible concept.

We are then, for various converging reasons, set upon the basic task of producing worthy *individuals* and a worthy *Society*. But which is the prime factor? This question has always been troublesome: For guidance let us turn first to King Alfred, who lived between AD 849 and 901. He wrote: *"Every man must say what he says and do what he does according to his ability."* This remarkably early appreciative penetration may be the first-ever recorded statement of the principle of Individualism. To clinch the matter let us turn to Olaf Stapledon's book *Waking World*, where he says: *"The sole justification of social organisation is that it is a means to the fulfilling of the capacities of individuals."* [1]. This brings out the point that human beings are first and foremost individuals and only secondly, and mainly by force of necessity and vastly enhanced effectiveness, social animals.

Building Stable Social Structures

We will then reject the vitiating Anthill concept of human organisation, of people existing for the sake of the State, and adopt instead as true the principle that Worthy Self-Expression (Individualism) is the END, Society the MEANS. Obviously, Society cannot be good unless people are good: From this it follows that if we want the best Government (Eutocracy) we must be worthy of it.

It becomes clear that the purpose of Society is to provide and sustain conditions conducive to meritorious individualism, to get the best out of each one of us, and to oppose the reverse. In particular, it becomes evident that whilst the personnel of an Extraterrestrial Base might be expected to accept a good deal of cultural and recreational deprivation over tours of duty as long as several years, *permanent Colonists – and their descendants, who had no choice where and under what conditions they live* – must have satisfying environmental conditions and wide-ranging amenities. Manifestly, on humanitarian grounds, extraterrestrial colonization cannot be of the primitive frontiersman sort but must provide expansile technological and social amenities of all circumstantially permissible kinds.

Conditions in an ET Colony must be made eminently desirable, or few people will emigrate. This high standard of diverse interests and living, of advanced Civilization, Culture and Wisdom [2] must certainly apply to manned interstellar voyaging, where generations may pass before a planet suitable for colonization is reached. To sum this point, it must be remembered that extraterrestrial activities, both near and far, are for the benefit of complexly thinking, complexly sensitive *people*, not cold insensate *machines*. *For these and other reasons, it seems evident that SELF-SUFFICIENT ET Colonization is technologically and socially much more exacting, and so more remote in time and perhaps distance, than is often envisaged.*

Just as it is apparent that an ET Colony must be highly and competently organised technologically to cope with Nature, so must the Community be highly and competently organised to cope with *people*. In learning to master Nature we must not forget to master ourselves. It may then be asked what needs to be done to realise an extraterrestrial Eutopia (for nothing less than The Land of Felicity is worth attempting), when we are obviously not running our home planet properly [3].

It is easier to start right than right wrong. There will also be the advantage of the Colony being a single Nation, not, as at present on Earth, a mass of interdependent conflicting autonomous States. The essential practical requirement is that the Constitution and Social Charters for an ET Colony must be developed and continuously implemented in all Departments, including Politics, by scientific analysis and synthesis of human needs and aspirations [4]. If this is done, it becomes evident, for example, that Economics and Finance cannot be left to the boom-and-bust haphazards of a free-wheeling Society: in the especially difficult environmental circumstances of an ET Colony, it would be asking for chaos, ruin and extinction. On the other hand, much social good can stem from individual enterprise – and we are committed to meritorious individualism. Indeed, as Emerson pointed out: *"All history is a record of the power of minorities, and of minorities of one."* The balanced answer is that, whilst there can be scope for a private sector, there must be a strong, interknit public sector to safeguard the stability of the Community's operations, i.e. those things vital to the Community must be owned, or at least controlled, by the Community, and with emphasis on Cooperation, not Competition. Indeed, a Government which does not have control of the Economy is no Government.

Social Charters

It is impossible to detail here the *why* and *how* of all the aspects and points of the Constitution and Social Charters which must be evolved as the foundations of an ET Colony, but all must know where they stand, and the questions of producing and distributing the Community's products must receive attention.

Obviously, production for a Self-Sufficient ET Colony will not be allowed to commence and proliferate in an uncontrolled manner. On the contrary, the furnishing of all vital things, utilities and services will doubtless be viewed as basically a matter of resources, technological potential and labour available to meet the stage-by-stage scientifically assessed and scientifically planned requirements of the Community. Since the minimization of drudgery and toil will doubtless be one humanitarian aim, we may take it that Mechanization and Automation will be maximised as soon as the Community is large enough to render this the most effective way of working. Initially, however, with only a small number of people involved, a Do-It-Yourself Cottage-Industry type subsidiary production may have to be operated, though even so machines will be needed.

Clearly, remuneration cannot be based on the individual's own opinion of personal value in all interests, in and out of Society. Distribution of the necessities and amenities will then depend, as nearly as possible in practice, upon the assessed relative value of each job to the Community. We can then say, as a matter of idealistic principle: *From each according to ability, to each according to social merit and the Community's resources.* However, it should be noted as particularly applicable to a vulnerable ET Community that, if the technology or sociology, or both, are inadequate or faulty, it is impossible to guarantee a satisfactory standard of living even if all things are shared equally.

Another point is that the population of an ET Community cannot be allowed to outrun the technological capacity to maintain it. On the contrary, and in flat scientific contradiction to an irresponsible religious prescript, which is apparently hell-bent on having a huge starving population to glorify God, birth control is an inescapable *must* – an inescapable *must* for medically conserved humankind, wherever it may be located. Incidentally, Earth's population cannot be stabilised by ET emigration, simply because the current daily gain of 200,000 people presents an impossible transportation problem.

Since vegetation of all useful kinds will be taken by ET

Colonists, for compactness sake doubtless in the form of seeds, spores, etc. – it is then apparent that some considerable growth-time must elapse before an ET Colony becomes fully established with food and other products derived from vegetation except, possibly, in the case of a Stellar Colonization where the destination planet may have its own suitable prolific vegetation. On the other hand, if the interstellar *Ark* is (as may necessarily be) capable of self-sufficiency over an indefinitely long period, then it may be only a matter of settling the *Ark* into a suitable orbit around the destination Star and switching from atomic power to solar power.

In contrast, the transportation of animals across Space and their maintenance in an ET Colony, presents considerable difficulty. Among these are problems of feeding (especially the carnivores) and additional pollution, even if it is assumed that biological science has advanced to the stage where only sperm and ova are initially needed and that it is possible to store these items for long transit periods in a dormant condition. The prime reason for stocking an ET Colony with animals, birds, fish, insects and other living things would be for food. However, it is likely that by the time ET Colonization becomes entirely practicable, fully acceptable alternative foods will have been developed, replacing everything the animal kingdom now furnishes. Furthermore, we may have decided by then that the breeding, constraint and butchery of animals for food (to say nothing of vivisection) is cruel, degrading and unacceptable. But to be entirely deprived of instructive and pleasurable association with animals is an almost unthinkable loss. A technologically competent and fully established ET Community would then, probably, admit the need for a conserved animal population, perhaps as an extension of those already being kept, as naturally as possible, in zoos.

Conclusion

We have now dealt with as many aspects of ET Colonization as possible here. However, some people may think that I have omitted the greatest consideration of all – the place of God in our future. I will therefore conclude by saying that, in my opinion, the royal road to a real knowledge of God (if indeed there *is* a Creator) is not through Speculative or Revelational Theology but by scientific study of His works, large and small, throughout the Cosmos.

NOTES

1. Dr. Olaf Stapledon, a distinguished author (*Last and First Men – A Modern Theory of Ethics – Star Maker* – etc.), was an early member of the BIS.
2. The following are my own definitions:-

CIVILIZATION,	is the humanitarian exploitation of power over Nature – provides the creatural comforts of life.
CULTURE,	is the refinement and elevation of the human mind and human activities – provides the intellectual comforts of life.
WISDOM,	is the possession of knowledge and experience together with the power of their critical application – the Art of knowing what to do with knowledge.

3. EUTOPIA,Spelt E U T O P I A... From the Greek EU meaning WELL, and TOPOS meaning PLACE; in combination signifying The Land of Felicity. State in which the technological potential and social organisation are in harmony. A Meritocracy based on Individualism; progressive in Civilization, Culture and Wisdom, and therefore dynamic.
4. See *The Scientific Attitude*, by Dr. C. H. Waddington...*"Man is the only animal to discover the secret of getting results in this material world, which is to let one's actions be governed by an objective analysis of the situation. Our task now is to enable this analysis, which we call science, to get results when it is applied to politics."*

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

NASA REVIVES PIONEER 11 INSTRUMENT

A scientific instrument aboard the Pioneer 11 space probe is operating again after lying dormant for three years and seems to be in good shape for use when the spacecraft encounters the ringed planet Saturn next year to take close-up pictures and make other first-time measurements.

The instrument is a solar plasma analyzer which maps the flow of the million-mile-an-hour solar wind, the streaming gas of ions and electrons which continuously flows from the Sun across the Solar System. The instrument will provide important information about the interaction of solar wind particles with Saturn and its rings. Investigators will compare these data with data gathered by the instrument three years ago when Pioneer 11 swung around Jupiter.

The instrument operated properly during Pioneer 11's 21-month, 1,000 million kilometre (620 million mile) journey from Earth to Jupiter, which it reached in December 1974. The spacecraft then flew up around Jupiter from pole to pole, using the planet's enormous gravitational field to help propel it high across the Solar System on its way to Saturn – 160 million km (100 million miles) above the orbital planes of most of the planets. The instrument ceased operation shortly after Jupiter encounter.

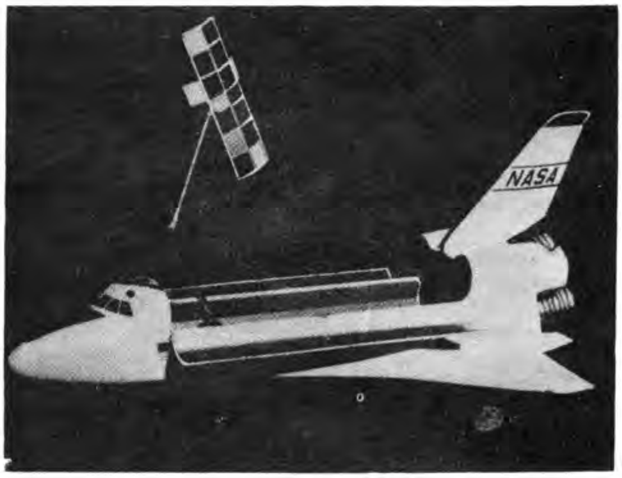
Then in October 1977, after exhaustive analyses of the instrument and the sending of a variety of commands, none of which worked, researchers decided to send radio commands to turn on the instrument's high voltage power source in an attempt to "thermally shock" the output circuits into operation. The effort apparently worked. Thirty-six days later, NASA tracking stations reported the first transmission of data in nearly three years. Since then the solar wind instrument has responded to all radio commands and appears to be in good working order for the Saturn encounter.

As Pioneer 11 approaches Saturn, it will slowly descend from a high arcing trajectory that enabled it to see phenomena from 160 million km (100 million miles) above the plane of the ecliptic (the plane in which the Earth orbits the Sun). This distance would measure 17 degrees above the solar equator as seen from the Sun and is the highest above the ecliptic that any spacecraft has ever flown. At present the probe is travelling through this uncharted space which is dominated by the solar wind.

An important recent finding of Pioneer 11 is related to the character of the Sun's magnetic field. It appears the Sun has a simple dipole field as viewed from the perspective of the interplanetary medium far from the Sun. That is, it has a relatively simple north pole and south pole configuration (a dipole) similar to Earth's, at least at this phase of the

solar cycle. Scientists now believe this finding of a dipole field is a basic discovery which may apply to virtually every star in the Universe. Ground-based observations indicate that the solar fields on the Sun's surface are normally quite complex even when viewed with coarse spatial resolution.

The trajectory of Pioneer 11 on its way from Jupiter to Saturn carried it through an electrical "current sheet" and into the Sun's northern magnetic hemisphere. NASA investigators discovered that this current sheet weaves through the solar equatorial plane like a warped disc and divides the spherical space around the Sun (the heliosphere) into roughly even northern and southern magnetic hemispheres. This heliosphere is the region filled by the solar wind surrounding the Sun and extending far beyond the Earth, at least as far as Pioneer 11 has measured to date.



Model showing Long Duration Exposure Facility (LDEF) being deployed in space from the Space Shuttle Orbiter. The re-usable, unmanned, free-flying structure will carry many different technical and scientific experiments in special trays. It provides an easy and economical way to conduct primarily passive experiments in Earth orbit.

National Aeronautics and Space Administration

COMING – A SPACE BONANZA!

A study just completed for NASA indicates that a world of pocket telephones and solar-powered homes and factories may be nearer than we think. It also concluded that while sales of services originating from space are already producing world-wide gross revenues of more than $1,000 million a year, by the year 2000 the figure will have grown to $10,000 million to $20,000 million with only minor advances in present technology.

These conclusions were reported in the summary of a space industrialisation study recently completed for NASA's Marshall Space Flight Center in Huntsville, Alabama, by two companies, Rockwell International and Science Applications, Inc.

The report stated that, with technological advancements in power production, structures, transportation and materials processing, earnings from space could well reach the $40,000 million a year mark or beyond.

Space industrialisation is already an international and multinational endeavour, with approximately 111 nations actively participating. At least five nations are now sponsoring materials space processing research with at least three organisations or nations actively conducting launches.

Of the four general categories of space industrialisation, it is Information Services that is nearest to maturity. Commercially owned satellites that provide communications and information on Earth resources and weather are already producing revenues. The remaining categories – products, energy and people in space – will require new technologies before markets can be opened up.

The Science Applications study predicted that, by 1985, 100,000 new jobs could be created in the United States alone as a direct result of a space industrialisation programme that includes development of technology for a satellite power system. Such a programme would generate $800 million in tax revenues, but the total impact to nation's economy would be much greater because of the many indirect jobs and services that would be made possible for these space industries.

By the year 2010, according to the study, new space industrialisation jobs would increase to 1,900,000 and tax revenues to $20,000 million. The contribution of the programme to the gross national product (in 1976 dollars) would be from 200,000 to 800,000 million dollars and the balance of trade impact could be as much as $50,000 million.

One of the more interesting services that could be provided from space is the wireless pocket telephone, operating *via* satellite and offering almost instant communications with any part of the world. For instance, a paramedic in a remote African village would be able to get the best possible emergency medical advice by calling a medical specialist in New York, London or any other city of the World. A businessman would have instant contact with associates and access to job and marketing information on a world-wide basis.

In the United States, satellite-linked portable telephones could be used by police, paramedics and other professional or semi-professional people, as well as the general public. The study predicted a long distance toll rate of about 20 cents.

The same space platform that provides telephone service may also provide direct broadcast educational television to homes, with five channels broadcasting programmes 24 hours a day. A home adapter for these broadcasts would cost less than $150, according to the report.

In addition to vastly improved communications, space industrialisation can provide energy and products. A satellite power system could produce energy from sunlight that would provide power for processing materials and operating systems in space, or as an alternative to coal and gas on Earth. Properly marketed, this power source could also be exported to other countries.

Energy availability appears to be the key to space industrialisation and the report recommends that its growth be divided into three 10-year intervals.

The Space Shuttle would be used to its fullest extent in the period of the 1980's. The centre of activities during this time would be in low Earth orbit with power provided by an orbiting power module like the 25 kW power module now being considered by NASA for early development.

Activities during this interval would include establishing a geo-stationary platform and a global weather and resources base to provide world-wide benefits. Later, a construction base, a space factory and a space operations centre could be established as one facility in low Earth orbit. Here, the capability to construct large space structures would be perfected as a step toward construction of the satellite power system.

In the second 10-year interval (1990's) the capabilities of the space factory, the geosynchronous platform and the global weather and resource base could be in use and initial operation of a satellite power system could begin. Beyond the year 2000, oxygen and materials for massive energy-

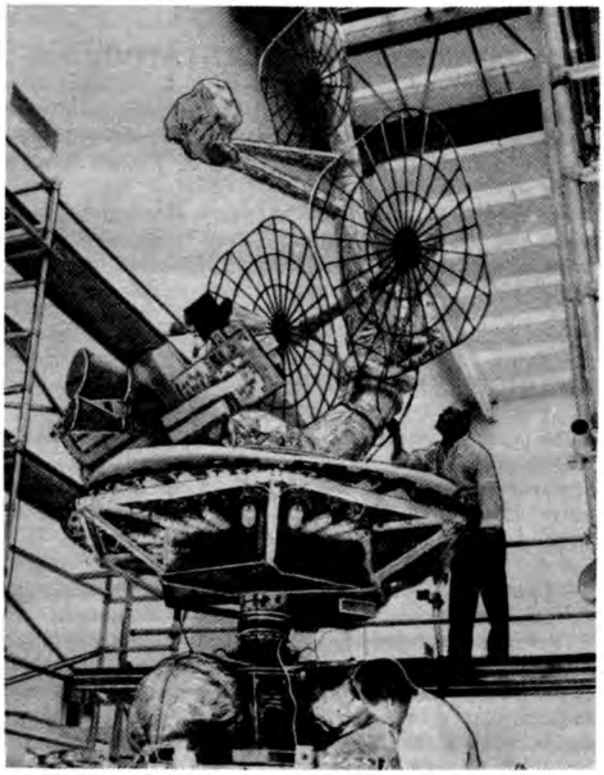
related projects at geosynchronous orbit would be obtained from the Moon.

Benefits in education, health and conservation of resources and productivity could be available to the entire world from information and observation services in the 1980's. The energy scarcity problem could be dealt with in the 1990's and, by the turn of the century, energy from space installations could become a worldwide energy source.

What will space industrialisation cost in terms of taxpayer dollars? The Rockwell report states that the government cost of providing the opportunity to use the pocket telephone is about 33 cents per person per year. Annual per capita costs for other services the space industrialisation programme could make available include: direct broadcast education (five channels), 33 cents; world medical advice centre, 20 cents; national information service (Library of Congress), 39 cents. None of these costs cited include user charges.

Throughout the entire programme, services would continue to be expanded, new products would appear, and research would move toward full understanding, prediction and localised control of Earth's weather and climate.

The study predicts that in the future the public will become increasingly involved with space, first by directly receiving immediate and tangible benefits and later by directly participating in the space activity itself – even in space travel.



Thirteen years to the week after tiny Early Bird (Intelsat 1) rocketed into geo-stationary orbit, the sixth and final Intelsat 4A communications satellite was successfully launched on 31 March from Cape Canaveral, Florida. Picture shows an engineer at Hughes Aircaft checking the antenna assembly. The satellite later was placed over the Indian Ocean to join a necklace of such spacecraft that have helped reduce the costs of international communications. The global Intelsat chain will carry colour coverage of the 1980 Moscow Olympics "live *via* satellite."

Hughes Aircraft Company

SALYUT-SHUTTLE DOCKING MISSION

During November, 1977, Soviet and American specialists met in Moscow to discuss experiments which might be performed during a joint flight of a Salyut type orbiting laboratory and a Space Shuttle, writes Robert D. Christy.

A number of areas of research were identified in the fields of astronomy, biology and engineering which could be carried out within the framework of a flight programme. No commitment was made by either side to include any of them on the flight but further study and discussion meetings were set up beginning in April, 1978. A separate group was organised to study the operational aspects of the flight.

The preliminary proposal is that the Shuttle would carry a 20 tonne payload into orbit, up to 10.5 tonnes of which could be left attached to the Salyut. The two vehicles would operate in a docked configuration for five days after which time the Shuttle would depart leaving a 16 metre long, 4 metre diameter experiments package behind to be operated by the Salyut crew for up to six months.

The mission would be flown in a 51.6 degree inclination orbit at a height of 350-400 kilometres, a similar one to that used by the current 'civilian' type Salyut. The Shuttle would carry two crew and up to five scientists to operate the experimental equipment. The Salyut crew complement would be two, this piece of information along with an unannounced Salyut mass of 26 tonnes suggests that a Soyuz ferry vehicle would also be involved.

FIRST SHUTTLE CREW

NASA has named the two astronauts who will crew the first orbital flight of the Space Shuttle Orbiter in June 1979. Both men are serving US Navy personnel. Captain John W. Young, the Commander, and Commander Robert L. Crippen, Pilot, will fly the Orbiter 102 on a three-day orbital test flight. It will be America's first manned space flight for nearly four years, and the country's 32nd manned space mission.

As one of America's most experienced spacemen John Young (born 24 September 1930, San Francisco, California; divorced, two children, subsequently remarried), will become the first man to make a fifth trip into space, writes David J. Shayler. His NASA service record is impressive: Group 2 pilot astronaut selected 17 September 1962; Pilot Gemini 3 23 March 1965, first US two-man flight; Backup Pilot Gemini 6; Command Pilot Gemini 10, 18-21 July 1966, rendezvous and docking mission; backup Senior Pilot for an 'early' Apollo, reassigned backup CMP Apollo 7; CMP Apollo 10 18-26 May 1969, first man to fly solo in lunar orbit; backup Commander Apollo 13; Commander Apollo 16, 16-27 April 1972, ninth man to walk on the Moon; replacement backup Commander Apollo 17; Chief, astronaut group assigned Space Shuttle programme, January 1973; Acting Chief Astronaut Office, April-June 1974; June 1974-April 1978 Chief Astronaut Office: also Chief Flight Operations Astronaut Office, Space Shuttle Programme. Young, who has already logged a total of 533:34 hours in space, is the second man to fly four missions, is credited with a lunar surface stay time of over 71 hours and 20 hours 15 minutes during three periods of lunar EVA. He was the seventh American to fly in space.

Young's fellow crew member on this historic flight is Robert Crippen, (born 11 September 1937; Beaumont, Texas; married three children) a space rookie and an ex-MOL (Manned Orbiting Laboratory) crew member, selected by the USAF for the project on 17 June 1966 (Group 2) serving in the capacity of crew member, until its cancellation on 10 June 1969; transferred to NASA; one of the Group 7, Ex-MOL Astronauts, 14 August 1969; Commander

Skylab Medical Experiment Altitude Test crew performed for 56 days; Support crew Commander for all three Skylab flights in 1973/4 and for ASTP in 1975. Bob Crippen will become the 44th American in space and the first of the Group 7 astronauts to orbit the Earth.

Also named are astronauts who form the first mission's backup crew; Air Force Colonel Joe H. Engle, Commander, and Navy Commander Richard H. Truly, Pilot (these two astronauts served as the second crew for the Shuttle ALT's in 1977. Later Shuttle orbital test flights will be flown by astronauts Fred Haise, Gordon Fullerton (both served as ALT's Crew 1), Jack Lousma and Vance Brand.

NASA plans six such test missions before the Shuttle becomes fully operational in mid-1980.

FLEETSATCOM ON STATION

The most advanced communications spacecraft ever orbited by the United States Department of Defense was declared operational on 4 April 1978 after more than 50 days of in-orbit testing. The satellite, called FLEETSATCOM, was launched on 9 February from Cape Canaveral. It serves as the space link in the U.S. Navy's fleet satellite communications system. In addition, the satellite provides vital communications capabilities for the U.S. Air Force and other users.

Since achieving orbit, the three-axis stabilised satellite has been tracked, controlled and evaluated by the Air Force Satellite Control Facility in Sunnyvale, California.

Two additional spacecraft are programmed to join the FLEETSATCOM system with the next launch possibly coming late this year.

Acquisition of the FLEETSATCOM space segment was managed by the Air Force Space and Missile Systems Organization. The satellite was manufactured by TRW's Defense and Space Systems Group.

POET IN SPACE FILM

Shooting has begun on a major film in the Soviet Union depicting the life of Konstantin Tsiolkovsky, the humble schoolmaster who became Russia's "father of cosmonautics" at the turn of the century.

The film, called *Take-Off,* is being directed by Savva Kulish with the Soviet poet Yevgeny Yevtushenko in the main role.

MORE UK COMSAT BUSINESS

Once again Britain has won valuable international contracts in the space communications business. Contracts valued at $75 million have been awarded to the Stevenage Space Division of British Aerospace Dynamics Group following the recent approval of the European Space Agency's ECS (European Communication Satellite) and Marots B (a maritime version of ECS).

British Aerospace will lead the MESH Consortium of European Companies and the payload contractors* in West Germany, the United Kingdom and Italy in these important programmes. This follows the announcement made in October of last year when an initial release of funds of £3.47 million was made for the development of ECS.

ECS will be a fully operational regional communications satellite and will be capable of carrying a significant proportion of future European telephone, telex and TV traffic. The contract award covers the provision of a satellite in orbit and a spare on the ground. A further two or three satellites will need to be developed and launched during the 1980's. Starting in 1981 the satellites will be launched by the European Ariane launch vehicle from the equatorial launch site at Kourou in French Guiana.

ECS will be based on the technology of the European Space Agency's Orbital Test Satellite (OTS), also built by the MESH consortium.

The MAROTS B satellite is a Maritime version of ECS comprising an identical service module, but with a completely different payload to meet the different mission requirements. The modular spacecraft concept, which was developed for OTS, has been retained in ECS to make this multi-mission capability possible. MAROTS B will provide direct telephone and telex links between ships in distant oceans and shore stations in the UK and elsewhere, giving a much needed improvement in quality and capacity over existing facilities.

The two MAROTS B satellites covered by the present contract award will provide Indian Ocean and possibly Atlantic Ocean coverage, as part of the world-wide system presently being offered by the European Space Agency to the international maritime community. These first two satellites also will be launched by Ariane from Kourou starting in 1980.

Further orders are hoped for to complete this world-wide system. The MESH consortium comprises MATRA (France); ERNO (West Germany); SAAB-SCANIA (Sweden); BRITISH AEROSPACE (Stevenage, United Kingdom); AERITALIA (Italy); FOKKER-VFW (Netherlands), and INTA (Spain).

NASA EUROPEAN REPRESENTATIVE

James R. Morrison has been appointed NASA's European representative in Paris. He succeeds Walter P. Murphy who returned to a new NASA assignment in the United States in March.

For the past three and one half years, Morrison has been manager of the Earth Resources Survey Program in NASA's Office of Applications. Prior to that assignment, he served for 12 years in NASA's Office of International Affairs.

AIR-DROPPED BOOSTER

The parachute recovery system for the Space Shuttle's Solid Rocket Booster has been tested to its full design limits in an air-drop at the National Parachute Test Range at El Centro, California. The drop was completely successful. It was the fourth test of the recovery system in which a dummy booster was carried aloft beneath the right wing of a B-52 aircraft. All three main parachutes in addition to the pilot and drogue parachutes were deployed in the test.

Two high-speed sled tests were conducted successfully recently under the same test programme. Conducted at the Sandia sled track in Albuquerque, New Mexico, these were designed to determine if the nose cap of the system, when ejected, would clear the vehicle without becoming entangled. The results showed that the cap cleared the system's drogue pack and deployed the pilot parachute as planned. The tests occurred in early March.

When the Space Shuttle flies in 1979, the two Solid Rocket Boosters used on each launch will separate after burnout at an altitude of about 43.5 km (27 miles). The parachute systems now being tested will lower them gently into the ocean for subsequent retrieval and reuse.

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* *Payload for ECS is provided by AEG/TFK (W. Germany), that for MAROTS B by MSDS in the UK.*

DISUNITY IN PLANETARY RESEARCH

In an open letter to the Director General of the European Space Agency and other officials, concern has been expressed about the lack of a unified European planetary programme. The letter is signed by S. K. Runcorn, former President of the IAU Commission on the Moon, on behalf of 47 lunar and planetary scientists from some 45 European laboratories, writes Geoffrey Lindop.

A discussion amongst the signatories of the letter, during the Ninth Lunar and Planetary Science Conference at JSC on 14 March 1978 established a need for European participation in future planetary missions like the Luna Polar Orbiter and cometary probe missions. This conclusion was reached after members of the ESA Solar System Working Group outlined the feasibility of using the Ariane Launch Vehicle for such projects.

European scientists have over the past 10 years developed an expertise in planetology by involvement in Apollo and Luna Sample Analysis Experiments in collaboration with the United States and the USSR.

So far European researchers have worked independently of each other and of ESA. By its diffuse nature the group felt that there was ignorance on their part of ESA activities, and of ESA on the activities of the European involvement in planetary analysis.

The letter was sent with the intention of strengthening these ties, and of developing a European Planetology group, possibly along the lines of the American Lunar and Planetary Institute in Houston.

EUROPEAN SPONSORED SPACELAB MISSIONS

Earlier this year, the European Space Agency, in agreement with the German authorities, made a call for experiments for four European-sponsored Spacelab missions currently envisaged to take place in 1982 and 1983. Two will be ESA missions (micro-gravity and Earth-oriented) and two (micro-gravity and deep-space-oriented) will be German sponsored with other European participation.

The first Spacelab flight, scheduled for the end of 1980 (one purpose of which is to verify the Spacelab/Shuttle system), will carry multi-discipline, joint ESA/NASA experiments. The four European-sponsored missions now announced mark the start of a permanent Spacelab utilisation programme in Europe.

The new call for experiments, sent to more than 2,000 scientists, institutes and industrial companies, allows a very wide European participation in Spacelab utilisation. Eligible were researchers in the 12 countries participating in ESA's Spacelab utilisation programme (Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland, United Kingdom) and in Canada and Norway which, like Austria, have observer status in ESA.

Costs will be borne by the participating countries according to their share of the payload. Proposers have been advised to seek sponsorship from their national authorities at the same time as they reply to the ESA call for experiments. All experiments whose mission implementation costs are covered by the experimenter's national authorities are being accepted for one of the four new missions envisaged, provided that they comply with safety requirements and do not conflict with the overall mission objectives.

ESA is reserving space free of charge on its first two Spacelab missions for experiments proposed and provided by young Europeans, for which a call will be made in 1979/80. Similarly, ESA will soon make a specific call for experiments in the field of educational physics, also to be carried free of charge on both these ESA missions. The latter experiments will be designed to film for educational purposes experiments illustrating fundamental laws of physics such as the conservation of momentum, and heat transmission without convection.

The main disciplines that benefit from the micro or near zero-gravity environments are:

Material Sciences and Space Processing

By isolating the effects of gravity, Spacelab will provide new opportunities for applied research on materials, which could lead to the processing in manned space laboratories, free of contact with containers, of ultra-pure metals, semiconductors and glass for use in electronics, laser technology and optical products. New composite materials having improved strength at high temperatures could also be produced, as well as perfect crystals for computers, communications and other electronic uses.

Life Sciences

The extremely stable, micro-gravity environment of Spacelab will be ideal for highly delicate separation methods used to isolate biological materials in order to obtain pure preparations of cells for transplantation, to prepare concentrated antibodies and to purify vaccines by eliminating contaminants that cause side-effects. The equilibrium adaptation process in the micro-gravity environment and ways to alleviate the problems of space-sickness also will be studied.

Earth-Oriented Mission

Priority on this mission will be given to atmospheric sciences, Earth observation and geodesy. In Earth observation, emphasis will be placed on experiments designed to develop methods of undertaking continuous, all-weather monitoring despite cloud cover. Experiments from other disciplines such as communications and navigation could also be included if compatible with mission constraints.

Deep-Space-Oriented Mission

Preference on this mission will be given to astronomy and astrophysics but solar physics experiments could be included if compatible with mission constraints. The mission objectives will be kept as broad as possible to include infra-red, optical, soft X-ray, hard X-ray and gamma astronomy.

INDIA-ESA COOPERATION

The Indian Space Research Organisation (ISRO) and the European Space Agency (ESA) have signed a new agreement to strengthen their existing friendly relations and to establish mechanisms that would foster cooperation in the peaceful uses of outer space. The agreement was signed by Prof. S. Dhawan, Chairman, ISRO, and Mr. R. Gibson, Director General, ESA, at Bangalore on 14 April.

The new agreement defines the areas of cooperation and lays the ground-work for periodic consultations on matters of mutual interest, coordination of efforts made towards the definition and realisation of common objectives, information exchange visits by scientists, award of fellowships to scientific and technical personnel, making available test facilities owned or used by one agency to the other, and tracking and telemetry support of each other's satellites.

The areas of cooperation defined in the Agreement include satellites, sounding rockets and balloons for space research and other applications such as communications and remote sensing.

The agreement is the outcome of growing cooperation between ISRO and ESA since 1971. A major example of cooperation between the two agencies was their October 1977 Agreement on the carriage of ISRO's experimental

geostationary communications satellite (APPLE) on-board the third development flight of Europe's Ariane launcher scheduled in early 1980.

SPACE POWER PROSPECTS

"The time has come either to prove the immense promise of solar power satellites or to seek other solutions to the energy problem in the United States," said Mr. Ralph Nansen, manager of space-based solar power systems for the Boeing Aerospace Company. Speaking at the 40th annual news conference of the Aviation/Space Writer's Association in Atlanta, Georgia, he pointed out that studies funded by the National Aeronautics and Space Administration and the federal Department of Energy have shown that a significant amount of America's energy needs could be met through the use of solar power satellites.

These satellites, deployed in geosynchronous orbit some 22,000 miles from Earth, would transform sunlight into microwave energy which would be beamed to large receiving antennae on Earth. These antennae would transform the microwave beam to electricity for use throughout the nation.

Each satellite promises to produce 10,000 megawatts of electricity, enough to light a million homes or run thousands of factories.

"We've gone about as far as we can go on paper," Nansen told the aerospace writers. These in-depth studies by Boeing and others have shown that technology either is here or within reach to build and operate these satellites. They also indicate that the job can be done as a cost allowing the production of energy at a cost competitive with that generated from fossil or nuclear fuels.

"But promises won't light lamps or drive machinery. We've done the homework and now are ready for the acid test: Concept and hardware verification."

The Boeing solar energy expert outlined a 10-point programme which would begin this task. The outline included work in these areas:

1. Automated production and refurbishment of low-cost, high-performance, light-weight solar cells.
2. Development of thermal engines and thermal control systems.
3. Development of microwave beam controls and determination of the effects of these beams on our environment.
4. Development and test of materials and fastening techniques for large space structures of sorts necessary for solar power satellite construction.
5. Determination of the effects of long-term space exposure on materials.
6. Development of control in space of large flexible systems.
7. Development and test of semi-automated construction equipment.
8. Design of new booster engines and electric thrusters.
9. Testing of concepts for power distribution and control on the satellite.
10. Impact of space plasma effects on large area systems.

Nansen said the verification programme could get off to an excellent start under funding provided by a bill now pending in the US House of Representatives. It provides $25 million in next year's budget specifically for solar power satellite verification and creates a solar power satellite programme office within the Department of Energy. A similar bill has been introduced in the US Senate.

"The creation of a programme office within DOE is an extremely important milestone," Nansen explained. "People tend to think of solar power satellites as a space programme. It is not; it is an energy programme. Our national space effort has reached a sophistication which can allow the realisation of great things for all of us on Earth. NASA will be the agency which allows it to happen, but the product will be usable energy and the customer will be you and me and our children.

"I use the phrase, 'will be,' because I strongly feel it will happen. But I – and my fellow engineers – can't prove it yet. That's the next step."

INTELSAT 5 ON THE WAY

Development of the Intelsat 5 communications satellite is proceeding, with a substantial contribution from Messerschmitt-Bölkow-Blohm. Seven flight units and over 150 ground stations are to assume world-wide communications duties between more than a hundred countries in the 'Eighties. Compared with its predecessor, Intelsat 4A, the new Intelsat 5 has, for example, double the number of telephone channels – 12,000 instead of 6250.

MBB is the biggest non-American contractor in the Intelsat 5 team led by the United States' Ford Aerospace company. The MBB package consists of the complete subsystems of the three-axis stabilisation system and solar generators. Never before on any Intelsat/COMSAT project have such complex tasks been entrusted to a company outside the United States. It should be mentioned that MBB's Intelsat 5 solar generator and three-axis stabilisation system are suitable for all launchers likely to be available in the future. This also applies in particular to Europe's launcher, the Ariane.

Design review of the three-axis stabilisation system and the solar generator has meanwhile been successfully completed, and their design has been approved by COMSAT, the customer. Development work at MBB has thus been terminated in the main, so that manufacture of the prototype and the flight units is beginning.

The Intelsat 5 team consists of Ford Aerospace (prime contractor), MBB (Federal Republic of Germany), Aérospatiale and Thomson-CSF (France), Marconi-SDS (United Kingdom) and Selenia (Italy). The first flight unit is to be ready for launch by mid-1979.

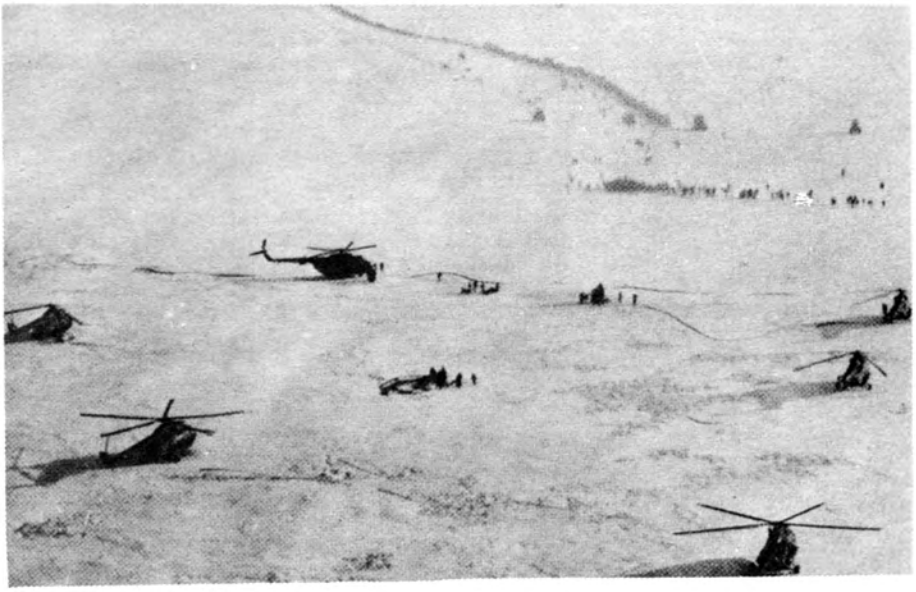
PROJECT DAEDALUS – FINAL REPORT

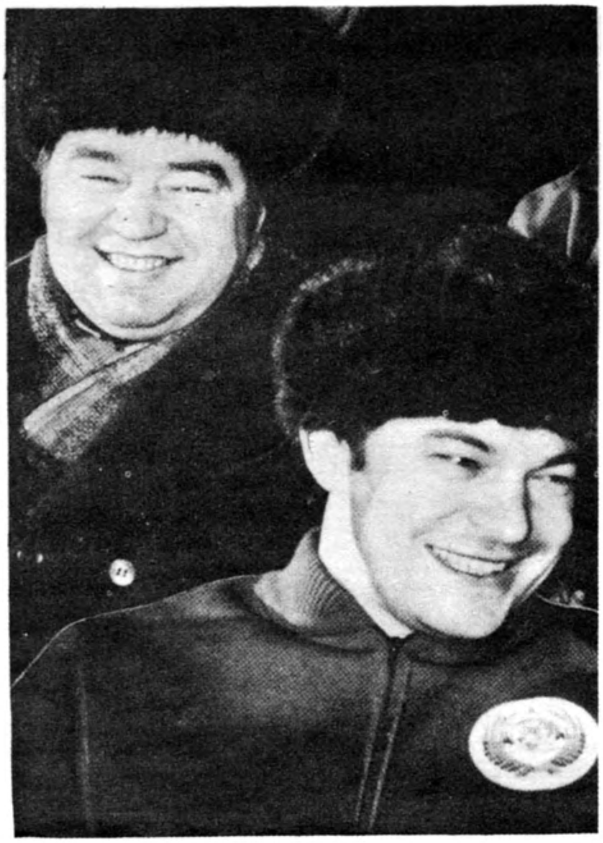
The Daedalus Final Report was published on 15 May. As the material to be included was rather more than expected, the number of pages went up from 160 to 192. Because of this, the price to non-members has also had to be increased, to £6.00 ($12.00). Members, however, may continue to order at the old price of £4.00 ($8.00) until 31 July, subject to stocks being available.

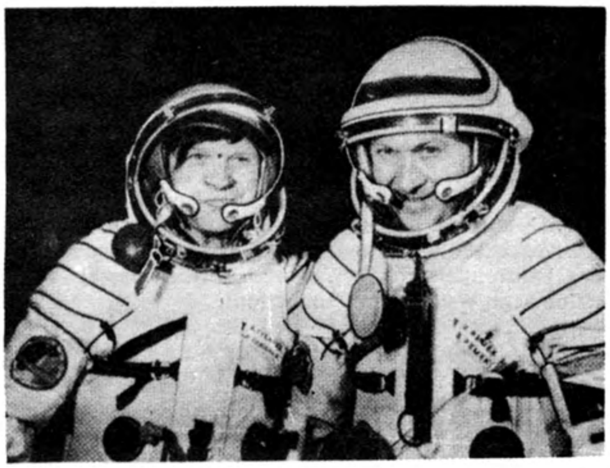
It is important to order without delay to take advantage of the present favourable rate. Copies from the second impression are likely to cost considerably more.

Orders and remittances to be sent to the Executive Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ.

SPACE CREWS RETURN. Russia's return to the forefront of space achievement has been marked by multiple dockings with the Salyut 6 space station and the first in-flight refuelling operation. These photos show the triumphant return of two of the crews. *Right*, search teams from Mi-8 helicopters subdue the landing parachute and help disembark cosmonauts Georgi Grechko and Yuri Romanenko after their record-breaking flight of 96 days 10 hours. *Right below*, rescue teams head for the Soyuz 28 capsule which contains the Russian cosmonaut Alexei Gubarev and Vladimir Remek, a Czech Army pilot. They had just completed the world's first international space flight.







Above, Georgi Grechko and Yuri Romanenko after their triumphant mission. *Right*, Gubarev and Remek back on Earth.

Novosti Press Agency

WHERE ARE THEY NOW?

By David J. Shayler

PART ONE

Introduction

Between April 1959 and August 1969 the National Aeronautics and Space Administration selected a total of 73 pilots and scientists in seven separate groups as astronaut trainees for the American manned space flight programme which ranged from Mercury through ASTP (Apollo/Soyuz Test Project) to the early test stages of the Space Shuttle.

By December 1977 a total of 31 astronauts remained on active flight status, 22 pilots and 9 scientist-astronauts (3 on inactive duty on other assignments but available for Shuttle flights)35 retired or resigned, and 8 deceased.

The purpose of this series is to reveal where all these 73 astronauts are at present and summarise their careers and achievements whilst with NASA. Each of the seven groups is dealt with in turn.

Group 1. Mercury Pilot Astronauts: 7 selected, 9 April 1959

Out of 508 suitably qualified military personnel who applied for astronaut selection in early 1959, a total of 69 of the most highly qualified were selected for a further series of tests. On the basis of subsequent interviews and tests 32 men were selected to undergo detailed physical examinations and stress training exercises, followed by a final screening on engineering and operational performance. Upon the completion of these tests a total of seven pilot-astronauts were named as candidates for the forthcoming Mercury project. These men, who became part of Space History, were 'The Original Seven.'

The Astronauts:

CARPENTER M. Scott, Cdr. USN (Ret.). Born 1 May 1925, Boulder, Colorado. Divorced, four children, subsequently remarried. Backup pilot Mercury 6; Pilot Mercury 7, 24 May 1962; Jan 1963 -1965 monitored design and development of Apollo Lunar Module, served as Executive Assistant to the Director, MSFC, Houston. Removed from flight status 1964 due to injuries sustained in a motorbike accident in Bermuda, temporary leave of absence 1965-67, participated in U.S. Navy's Sealab II project, spending 30 days underwater; first man to live in both inner and outer space; assigned to astronaut office for USN liason and underwater zero-g training. Retired NASA August 1967 to enter Sealab programme full time. Retired USN July 1969 due to decompression scars encountered within that project. President Sea Sciences Corporation until 1972; entered private business, interests include breeding of bug killing bees. Currently President Pyro-Sol, Incorporated, Los Angeles, California.

COOPER, Jr. L. Gordon, Col. USAF (Ret.). Born 6 March 1927, Shawnee, Oklahoma. Divorced, two children, subsequently remarried. Backup pilot Mercury 8; Pilot Mercury 9 15-16 May 1963; first American to spend 24 hours in space. Command Pilot Gemini 5 21-29 August 1965; backup Command Pilot Gemini 12. Backup Commander Apollo 10; thus became eligible to Command Apollo 13 lunar landing mission; he declined however and retired from NASA and the USAF in July 1970. Formed Gordon Cooper Associates in Florida; served with Academy of Defence Driving, East Irving, California; currently Vice-President, Research and Development, Walt Disney Productions.

GLENN, Jr. John H, Col. USMC (Ret.). Born 18 July 1921, Cambridge, Ohio. Married, two children. Backup pilot Mercury 3 and Mercury 4, selected to make third suborbital mission before it was cancelled as unnecessary. Pilot Mercury 6, first American to orbit the Earth 20 February 1962.

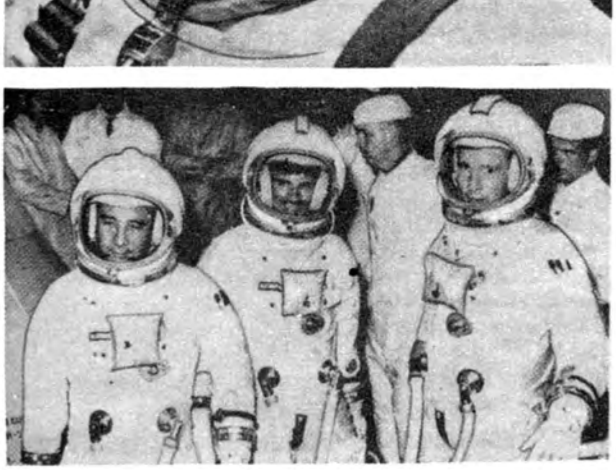
Major John Glenn, the first American to orbit the Earth on 20 February 1962.

National Aeronautics and Space Administration

January 1963-January 1964, worked on the Apollo programme; left astronaut corps January 1964 and served, for a short while, as Consultant to NASA's Administrator, until he left the space programme in February 1965. Joined Royal Crown Cola Soft Drinks Company as Director and to enter politics, joining staff of the Govenor of Ohio; he has continued in politics and in November 1974 he was elected Senator from the State of Ohio.

GRISSOM, Virgil I (Gus), Lt-Col. USAF (Deceased). Born 3 April 1926, Mitchell, Indiana. Married, two children. Pilot Mercury 4 21 July 1961, second suborbital mission. Command Pilot Gemini 3, first U.S. two-man flight 23 March 1965; first American to fly twice in space; backup Command Pilot Gemini 6; 21 March 1966 named Commander Apollo 1, first manned flight of the series scheduled for February 1967, also tentively assigned Commander seat on first lunar landing mission for a short while; died 27 January 1967 in Apollo 1 flash fire at Cape Kennedy. Buried at Arlington Military Cemetary, Washington.

SCHIRRA, Jr. Walter M., Capt. USN (Ret.). Born 12 March 1923, Hackensack, New Jersey. Married, two children. Backup Pilot Mercury 7; Pilot Mercury 8 8 October 1962; Backup Command Pilot Gemini 3; Command Pilot Gemini 6 15-16 December 1966, first space rendezvous with Gemini 7. Backup Commander Apollo 1; assigned Prime Commander Apollo 2 for a short while before being reassigned as



Above, the original 'seven'. *Top row, left to right,* Malcom S.Carpenter; Leroy G. Cooper, Jr.; John H. Glenn, Jr. and Virgil I. Grissom. *Bottom row, left to right,* Walter M. Schirra, Jr., Alan B. Shepard, Jr. and Donald K. Slayton.

Left, astronaut Ed White suited up ready to make America's first 'space walk' in June 1965.

Below, three men who gave their lives for the conquest of space, *left to right,* Virgil I. 'Gus' Grissom, Roger B. Chaffee, and Edward H. White. They died in the Apollo-204 flash-fire at Cape Canaveral on 27 January 1967. They were training to test Apollo command and service modules in Earth-orbit, possibly for as long as two weeks.

All photos: National Aeronautics and Space Administration

Commander Apollo 7 11-22 October 1968. First man to fly three missions; only man to fly in all three American pioneering space programmes (Mercury, Gemini, Apollo). Offered Command of an early Apollo lunar landing flight (Apollo 13 or 14) before retiring from NASA and the Navy in July 1969 to become Chairman of the Environmental Control Company, Englewood, Colorado and Chief Exectutive Officer of Regency Investigator Incorporated, a Denver-based leasing company. He subsequently became Chairman of the Environmental Control Company, and Sernco Incorporated, also as Chairman; he then became Director of Technology Purchase, Johns-Manville Corporation, Denver, Colorado. He is currently Director of Marketing-Powerplant and Aerospace Systems of the same company and Vice-President, Johns-Manville Sales Corporation.

SHEPARD, Jr. Alan B., Rear Admiral, USN (Ret.). Born 18 November 1923 East Derry, New Hampshire. Married, two children. Pilot Mercury 3 5 May 1961, first American in space, during 15-minute suborbital mission; Backup Pilot Mercury 9; selected for first manned Gemini in 1963 with

Tom Stafford; removed due to discovery of inner ear ailment; 1963 May 1969 Chief, Astronaut Office; restored flight status following corrective surgery May 1969. He was assigned to Commander Apollo 13 before rescheduled to Commander Apollo 14 31 January-9 February 1971, fifth man (and only one of the Mercury astronauts) to walk on the Moon. June 1971-April 1974 resumed duties of Chief, Astronaut Office, April-June 1974 Senior Advisor to the Acting Chief of the Astronaut Office (John Young). Retired NASA and USN, June 1974, succeeded as Chief, Astronaut Office by John Young. Became Partner and Chairman of the Marathon Construction Company. In July 1975 covered the ASTP mission for the NBC News Service; currently President of Windward Company, Deer Park, Texas.

SLAYTON, Donald K. (Deke), Major, USAF (Ret.). Born 1 March 1924, Sparta, Wisconsin. Married, one child. Selected to fly Mercury 7; removed from flight status due to discovery of slight heart murmour; mission flown by astronaut Scott Carpenter. Only Mercury astronaut not to fly in a Mercury-type spacecraft. Became Co-ordinator Astronaut Activities September 1962-November 1963; November 1963 resigned USAF commission to become Director Flight Crew Operations, serving in that position until March 1972 when following a review of his medical status he was returned to full flight status. February 1973 named as Docking Module Pilot for ASTP Apollo crew, relinquishing his role as Director of flight crew operations in February 1974 whilst training for the mission. Flown between 15-24 July 1975 the American Apollo docked with a Soviet Soyuz craft and conducted crew transfer exercises; currently Deputy Director Flight Operations, Approach and Landing Tests, Space Shuttle Program Office, JSC, Houston.

Group 2. Pilot Astronauts. 9 selected, 17 September 1962

In April 1962 NASA again issued a call for astronaut trainees for the Gemini and Apollo programmes; all applicants had to be of test pilot status. More than 200 applications were received and following medical examinations in June 32 of the most highly qualified applicants were put forward for further examinations, tests and interviews. Finally nine applicants were chosen by NASA to form its second group of astronauts sometimes known as the Second Nine.

The Astronauts:

ARMSTRONG, Neil A., Civilian. Born 5 August 1930, Ohio. Married, two children. Ex-pilot of the X-15 rocket plane making seven flights between November 1960 and July 1962; he was the seventh man to fly that aircraft, transferring to NASA in the following September. Backup Command Pilot Gemini 5; Command Pilot Gemini 8, 16 March 1966, first space docking, first emergency return due to malfunctioning thruster onboard the Gemini; Backup Command Pilot Gemini 11; Backup Commander Apollo 8; Commander Apollo 11,16-24 July 1969, first man to walk on the Moon, 20 July 1969. Played key role in development of Lunar Landing Training Vehicle. Stayed with NASA to become Deputy Associate Administrator for Aeronautics July 1970-October 1971. Left NASA October 1971 to take up position as First Engineering Professor of Aeronautics, University of Cincinatti, Ohio, a position he still holds at the time of writing.

BORMAN, Frank, Col. USAF (Ret.). Born 14 March 1928, Gary, Indianna. Married, two children. Backup Command Pilot Gemini 4; Command Pilot Gemini 7, 4-18 December 1965, set new space endurance record of 14 days, also rendezvous operations with Gemini 6; named Commander for an early Apollo flight, then for the third manned flight before being rescheduled as Commander for second manned Apollo flight. First to use the Saturn V launch vehicle; this of course became Apollo 8. 21-27 December 1968; one of the first three men to fly to and orbit around the Moon. Special duties whilst an astronaut included being a member of the Apollo 204 (Apollo 1) Review Board; in May 1967, he became Field Director, Long Term Space Station Programme for NASA. Assistant Flight Crew Operations Director in 1969 before leaving both NASA and the USAF on 1 July 1970 to enter private business and to become Deputy Chairman of Eastern Airlines; subsequently became Senior Vice-President, Operations Group and was recently promoted to President and Chief Operating Officer.

CONRAD, Jr. Charles, (Pete), Capt. USN (Ret.). Born 2 June 1930, Philadelphia, Pennsylvania. Married, four children. Pilot Gemini 5 21-30 August 1965; Backup Command Pilot Gemini 8; Command Pilot Gemini 11 12-15 September 1966. Backup Commander Apollo 9; Commander Apollo 12 14-24 November 1969, third man to walk on the Moon; became head of astronaut detachment assigned to Skylab programme and Commander of the first manned crew, Skylab 2.Flew between 25 May-22 June 1973 setting a new mission endurance record of 28 days. Conrad, who spent his 43rd birthday onboard Skylab 1, was the third man to fly on four separate space missions. He retired from NASA and the USN on 1 February 1974, became Vice-President and Chief Operating Officer of the American Television and Communications Corporation, a Cable TV firm based in Denver. In 1976 he became Vice-President Commercial Sales-International, McDonnell-Douglas Corporation, Long Beach, California; he was recently promoted to President of that Department. Following his retirement from NASA in 1974 he continued to serve as a Member of NASA's Space Systems Committee.

LOVELL, Jr. James A., Capt. USN (Ret.). Born 25 March 1928, Cleveland, Ohio. Married, four children. Backup Pilot Gemini 4; Pilot record breaking Gemini 7 4-18 December 1965; Backup Command Pilot Gemini 10 reassigned Backup Command Pilot Gemini 9; Command Pilot Gemini 12 11-14 November 1966. Backup Command Module Pilot third manned Apollo, reassigned Backup Command Module Pilot Apollo 8, subsequently assigned Prime Command Module Pilot Apollo 8, 21-27 December 1968; one of the first three men to orbit the Moon; Backup Commander Apollo 11. Commander Apollo 13, 11-17 April 1970, aborted lunar landing mission; lost chance of becoming the fifth man to walk on the Moon. First man to make four separate space flights. First man to fly to the Moon twice; became Deputy Director, Science and Applications MSC, Houston, May 1971-March 1973, when he retired from NASA and the USN; became President and Chief Executive Officer of the Bay Houston Towing Company, Texas; he resigned that position on 1 January 1977 and is currently President of Fisk Telephone Systems in Houston.

McDIVITT. James A., Brig. Gen. USAF (Ret.). Born 10 June 1929, Chicago, Illinois. Married, four children. Selected to fly the X-15 but instead chose to join the NASA programme. Command Pilot Gemini 4, 3-7 June 1965; Backup Commander for first manned Apollo for a short while before becoming spacecraft Commander for the second manned mission; reassigned Commander third manned mission, which eventually became Apollo 9, which,during 3-13 March 1969, first man-tested the Lunar Module in space. Manager of the Apollo Spacecraft Programme September 1969-September 1972, when he retired from NASA and the USAF to become Vice-President of the Consumer Power Company; currently Vice-President Pullman Standard Company, Chicago, Illinois.

SEE, Jr. Elliot M., Civilian (Deceased). Born 23 July 1927, Dallas, Texas. Married, three children. Backup Pilot Gemini

GROUPS 1 AND 2. Seated, *left to right*, Gordon Cooper, Gus Grissom, Scott Carpenter, Wally Shirra, J. H. Glenn, Jr., Alan B. Shepard, Jr., D. K. Slayton. Standing, *left to right*, Edward H. White, II, John Young, Charles Conrad, Jr., Neil Armstrong, James Lovell, James A. McDivitt, Elliot See, Frank Borman, Thomas P. Stafford.

National Aeronautics and Space Administration

5; named Command Pilot Gemini 9, killed before making flight on 28 February 1966 in a T-38 jet crash near St. Louis, Missouri.

STAFFORD, Thomas P., Maj. Gen. USAF. Born 17 September 1930, Weatherford, Olkahoma. Married, two children. Original Pilot Gemini 3, reassigned Backup Pilot Gemini 6, rendezvoused in space with Gemini 7, 15-16 December 1965; Backup Command Pilot Gemini 9, reassigned Prime Command Pilot Gemini 9 upon deaths of original Prime crew; flew mission during 3-6 June 1966. Senior Pilot of an 'early' Apollo backup crew; then Backup Commander of what eventually became Apollo 7, Commander Apollo 10, 18-26 May 1969, orbited the Moon during lunar landing dress rehearsal; Chief Astronaut Office August 1969-May 1971. Served as Deputy Director of Flight Crew Operations June 1971-February 1973; Named Commander of American ASTP Apollo flying that mission during 15-24 July 1975 in a joint docking exercise with a Soviet Soyuz spacecraft; possibly the most experienced Rendezvous and Docking astronaut of the NASA Corps. Retired from NASA 1 November 1975 to become Commander of the USAF Flight Test Center, Edward's Air Force Base, California, a position he still holds. He was the fourth man to make four space flights.

WHITE, II. Edward H., Lt. Col. USAF (Deceased). Born 14 November 1930, San Antonio, Texas. Married, two children. Pilot Gemini 4, 3-7 June 1965, first American to walk in space. Backup Command Pilot Gemini 7; nominated Command Module Pilot for Apollo 1, March 1966; died before the flight during the flash fire within capsule during simulated countdown at Cape Canaveral, Florida on 27 January 1967. Buried at West Point Military Academy Cemetary.

YOUNG, John W., Capt. USN (Ret.). Born 24 September 1930, San Francisco, California. Divorced, two children, subsequently remarried. Pilot Gemini 3, 23 March 1965. Backup Pilot Gemini 6; Command Pilot Gemini 10, 18-21 July 1966; assigned as Backup Senior Pilot for an 'early' Apollo mission, reassigned to Backup Command Module Pilot for Apollo 7. Command Module Pilot Apollo 10, 18-26 May 1969, first man to fly solo in lunar orbit; Backup Commander Apollo 13; Commander Apollo 16, 16-27 April 1972, ninth man to walk on the Moon; replacement Backup Commander Apollo 17. Assumed duties as Chief of Astronaut group assigned to Space Shuttle programme January 1973; April-June 1974 Acting Chief of Astronaut Office, JSC, Houston, becoming Chief in June 1974, a position he still holds at the time of writing, with additional duties in Space Shuttle development; also serves as Chief Flight Operations Astronaut Office, Space Shuttle Programme.

[To be continued.

SATELLITE DIGEST - 117

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information sources include the Royal Aircraft Establishment, Farnborough, NASA, Novosti and both the popular and specialist press. For a more detailed summary, see Satellite Digest – 111, January 1978.

Continued from June issue, p. 235]

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin- ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
EXOS A 1978-14A	1978 Feb 4.29 300 years	Cylinder 103	0.8 long 0.95 dia	642	3975	65.09	134.27	Kagoshima Mu-3H Japan/Japan (1)
Cosmos 988 1978-15A	1978 Feb 8.51 11.8 days (R) 1978 Feb 20.3	Cylinder + Sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	201	335	72.84	89.87	Plesetsk A-2 USSR/USSR
Fleetsatcom 1 1978-16A	1978 Feb 9.89 indefinite	Hexogonal cylinder 1884 fuelled	1.27 long 2.44 dia	167 35522	35978 35666	26.46 2.77	634.16 1426.1	ETR Atlas Centaur USN/NASA (2)
Cosmos 989 1978-17A	1978 Feb 14.40 13.8 days (R) 1978 Feb 28.2	Cylinder + sphere + cylinder-cone ? 6000?	6 long? 2.2 dia?	169	318	65.05	89.36	Tyuratam-Baikonur A-2 USSR/USSR
ISS 2 1978-18A	1978 Feb 16.17 1400 years	Cylinder 140	0.82 long 0.94 dia	975	1224	69.37	107.25	Tanegashima Nu Japan/Japan (3)
Cosmos 990 1978-19A	1978 Feb 17.69 120 years	Cylinder + paddles? 750?	2 long? 1 dia?	783	809	74.05	100.80	Plesetsk C-1 USSR/USSR (4)
NDS 1 1978-20A	1978 Feb 22.99 indefinite	Cylinder + 4 vanes 450?		20095	20308	63.27	718.67	ETR Atlas F DoD/USAF (5)
1978-21A	1978 Feb 25 unknown							ETR? Atlas-Agena D ? DoD/USAF (6)
Cosmos 991 1978-22A	1978 Feb 28.28 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	963	1009	82.98	104.84	Plesetsk C-1 USSR/USSR (7)

Supplementary notes:

(1) Scientific satellite designed to investigate the aurorae, also known as Kyokko (aurora).
(2) Military communications satellite for use by ships or military personnel in the field using small, mobile terminals.
(3) Ionospheric sounding satellite, also known as Ume 2.
(4) Cosmos 990 may be a military communications satellite.
(5) NDS stands for Navigation Development Satellite.
(6) US military launch for which data is being with-held.

Amendments and decays:

1968-95A, Cosmos 250 decayed 1978 Feb 15, lifetime 3395 days.
1977-66A, Cosmos 929 was de-orbited over the Pacific Ocean 1978 Feb 2, lifetime 200 days.
1978-03A, Soyuz 27 was recovered 1978 Mar 16.472, lifetime 64.953 days. It brought back Yuri Romanenko and Georgi Grechko from the Salyut 6 laboratory; they spent 96.417 days in space and were launched into orbit aboard Soyuz 26 (1977-113A).
1966-63A, OV1-8 decayed 1978 Jan 4, lifetime 4192 days.
1975-106A, Soyuz 20 was recovered 1976 Feb 16.1, lifetime 90.5 days.
1975-107A, Explorer 55, add a second orbit at 1976 Nov 23.0, 264 x 267 km, 19.66 deg, 89.82 min.
1976-12A, Cosmos 801 decayed 1978 Jan 5, lifetime 700 days.
1977-100E is a manoeuvring engine ejected from 1977-100A, Cosmos 958 during 1977 Oct 23.

SCOREBOARD 1977

Of the 124 launches during 1977, 98 were conducted by the USSR, yielding 105 payloads, writes Robert D. Christy. This figure includes one test of a satellite interceptor in spite of the fact that it did not complete one orbit. One Soviet launch placed the French built gamma ray satellite, Signe 3, into orbit. There were two manned space flights, both in connection with Salyut 6. Soyuz 25 failed to achieve docking and Soyuz 26 was the first craft to dock with a Salyut's second docking port.

The USA accounted for 24 launches, 10 of which were military; the other 14 were made by NASA including 10 satellites launched for other countries or organisations. Europe's OTS and an Intelsat 4A failed to reach orbit and another European vehicle, GEOS was left stranded in a transfer orbit on its way to geosynchronous altitude.

The only other nation with launchings during the year was Japan with two test satellites.

* * * * * *

BOOK REVIEWS

Foundations of Space Biology and Medicine
Eds. M. Calvin and O. G. Gazenko, 3 Vols. NASA SP374, 1975, U.S. Superintendent of Documents, Washington D.C. pp. 1740, $40.00

This publication, a joint venture between the Soviet Academy of Sciences and NASA, is a comprehensive summary of results in this field over the last 15 years. As stated in the foreward, "its purpose is a make available to specialists, summarised and systematised data on the most important problems of Space Biology and Medicine." Indeed, this is done admirably. The text, published in both English and Russian editions, is divided into 4 books, Volume 2 comprising books 2 and 3. Volume I, titled *Space as a Habitat*, is in 2 parts. The first, in 6 chapters, lays down the physical groundwork so that physicians and biologists may understand current data on the Universe, but mainly deals with the Solar System and its galaxy; in essence it is a primer of general astronomy and comparative planetology. Part 2 of this Volume, in 3 chapters, points out the various biophysical and biochemical properties of nature and how they relate directly to the problem of survival in space and the difficulties of designing apparatus in studying these phenomena and in the search for extraterrestrial life.

The first part of Volume 2, in 3 chapters, explores the influence of artificial atmospheres of spacecraft and stations on the organism, through the summarising of data on barometric pressure and gas composition, toxicology of the air in closed spaces and thermal exchanges and temperature stress. Part 2 deals with the effects of dynamic flight factors on the organism by analysing the principle of gravitation biology, and of accelerations of all types; separate chapters dealing with weightlessness and noise and vibration are included in this section.

Chapters 10 to 19 appear in Book 2 of Volume 2, which is in 3 sections. The first covers aspects of radiant energies from space and the organism; the second part studies the pathophysiology of space flight, the third discusses the variety of methods used in examining these effects and the transmission of this information.

Volume 3 reflects the present applications of research to the methods of providing life support for space crews, the design considerations for intergrating life support systems, protection against adverse factors of space flight, selection and training of Astronauts and finally plans and problems in future research.

With 46 chapters in all, each heavily referenced, this publication is an excellent review of present knowledge, in no way out of date. It summarises most of what we know about space life science and will probably assume the prominence of a textbook with continuous editions when manned flight and space-stations enter the realm of the commonplace in the 1980's. Presented on good quality paper with easy to read type, the organisation and comprehensibility make it that more enjoyable to read. There are over 1200 data tables, graphs, design figures and photographs, some in colour. With over 60 authors and editors contributing the technical accuracy and referencing is superb.

Though the title implies the study of the human condition based on the stresses of space flight and the search for non-terrestrial animation, no section deals specifically with the biomedical application of this science on Earth. The many advances in research techniques and clinical medicine that might have benefited, directly or indirectly, from this work, might therefore have been considered for inclusion. This might help to demonstrate the obviously important and exciting gains being made for the physician and patient in improving health care on *terra firma*.

Only one other point might need to be considered, i.e. the psychological, ethical and moral implications of discoveries and continuing research. These two points might have important consequences in helping to increase support for this science.

This publication is mainly a reference work and an impetus to further research. It is not recommended to anyone without solid academic grounding in the major life sciences. The treatise is primarily for physicians, bioscientists and comparative planetologists. Viking and pioneer probe results are not presented as such due to the date of publication. Nevertheless, this in no way detracts from the obvious value of the work.

DR. K. J. O'BRIEN

Novae and Related Stars
Ed. M. Friedjung, D. Reidel Publishing Company, 1977, pp. 228, $29.50.

This is an interesting and fairly extensive work with over fifty papers of varying length. Each of the six sections (with the exception of the final section comprising the Chairman's Summary) is divided between introductory review papers and "short contributions" which are generally summaries of more detailed papers subsequently published elsewhere, and to which the reader is directed.

The papers, forming the proceedings of a conference held in Paris in September 1976, are grouped as follows: Part I, on novae, dwarf novae and similar objects at minimum light is prefaced with a review of present and future novae by Cecilia Payne-Gaposchkin and which contains a very extensive bibliography. Part II relates to observation of novae and related objects during outbursts, there being two review papers. Friedjung discusses several possible simple models of the nova outburst and concludes the most probable model is one where most of the mass is ejected near maximum light and where ejection continues afterwards, whilst Mustel discusses the expansion of novae before light maximum and the formation of the principal envelope.

The papers comprising the third section are divided between those dealing principally with novae at the nebular stage and short contributions on transient X-ray sources. Section IV is entirely devoted to observations of Nova Cygni 1975 with the single review paper by Andrillat appearing in its native French! The penultimate section is of a theoretical nature and looks at the causes of novae outbursts. Sparks, Starrfield and Truran review the thermonuclear runaway model whilst Audouze and Lazareff examine nucleosynthesis induced during such outbursts.

As Friedjung comments in his preface to this volume (No. 65 in the *Astrophysics and Space Science Library Series*) there still remains a large gulf between theory and observation. However, much has been accomplished in recent years to further understanding of these fascinating and spectacular objects and there are now many researchers specialising in observation/theoretical work in this field. Shaviv, the Chairman of the Session, reminds us that the basic theoretical effort is directed at explanations of only the very gross features of nova phenomena e.g. energy requirements, total mass ejected, velocity in steady state flow, with little work regarding explanations of the fine features such as the internal structure of the expanding envelope and the affect

of non-spheral symmetry imposed by the existing secondary star. "The reasons are apparently the desire of theoreticians to get fast results or difficulties or both." However, justification would appear to lie in the fact that it is essential to understand the overall physics before working on the finer details.

S. G. SYKES

Essay on the History of Rocketry and Astronautics: Proceedings of The Third Through The Sixth History Symposia of The International Academy of Astronautics, Ed. R. Carghill Hall, NASA Conference Publication No. 2104, U. S. Government Printing Office, 1977, 2 Vols. pp. 714, $10.00.

On the occasion of the IAF meeting in 1967, the International Academy of Astronautics sponsored an historical symposium. Symposia organised by the Academy on the history of astronautics have since become an annual event of IAF Congresses, with proceedings published in Russian and English. The English language version of the first two symposia (Belgrade, 1966; New York, 1968 were edited by Frederick C. Durant, III, and George S James) appeared as *First Steps Toward Space: Proceedings of the First and Second History Symposia...* Smithsonian *Annals of Flight,* No. 10 (Washington D.C.: US Government Printing Office, 1974).

Cargill Hall has now edited English lagnuage printing of the papers presented at the third to sixth history symposia (Mar del Plata, 1969; Constance, 1970; Brussels, 1971; Vienna, 1972). Hall, a historian at the Jet Propulsion Laboratory, Caltech, and now with the Historical Office of the USAF Strategic Air Command, has arranged the 39 papers, in terms of their topical content, in four parts. Volume 1 includes: (1) "Early Solid-Propellant Rocketry"; (2) Rocketry and Astronautics: Concepts, Theories and Analyses after 1880"; while Volume II covers (3) "The Development of Liquid – and Solid – Propellant Rockets, 1880-1945"; and (4) "Rocketry and Astronautics after 1945."

The History Committee of the International Academy of Astronautics established a chronological limit for these and succeeding papers, stipulating that coverage should not extend beyond the period of twenty years prior to the date of each symposium, a limitation intended to avoid compromising security clearances and to assure a degree of historical perspective.

The eight selections of Part I begin with Roumanian rocketry of the 16th century, although most of the essays deal with the 19th century including Sweden, Hungary, and Spain, and two essays are essentially surveys of rocketry and astronautics in Spain and Poland that carry over into the early 20th century. Two of the longer and more cohesive papers in this group were written by Frank H. Winter and Mitchell R. Sharpe. Winter's study assesses the rise and fall of military rocketry in 19th century Austria, effectively pointing out the changing political and strategic influences affecting the "Raketenbatterien" of Baron Vincenz von Augustin.

Although the 19th century, Sharpe lucidly describes the rather extensive nonmilitary use of solid rockets in whaling, lifesaving, and commercial signalling at sea, in addition to miscellaneous 20th century rocket applications in such diverse roles as cloud seeding and terradynamics.

The nine essays of Part II include several on early Russian experimenters, including a brief review of S. S. Nezhdanovsky's consideration of jet engine propulsion, written by V. N. Sokolsky, and an abbreviated review of "The Ideas of K. E. Tsiolkovsky on Orbital Space Stations." There is an interesting survey of Guido von Pirquet's work on interplanetary routes and orbits, followed by Robert E. Roberson's worthy study of the "Evolution of Spacecraft Attitude Concepts Before 1952." The most extensive essay of this ection is a memoir of the career of Eugen Sänger, written by his widow, Irene Sänger-Bredt, who discusses Sänger's advocacy of aerodynamic space vehicles, the WWII "Raketenbomber," and work in advanced propulsion systems.

Volume II contains a higher percentage of contributions having greater length and depth of analysis. The 13 essays of Part III begin with V. N. Sokolsky's interesting synthesis of the historical patterns of 19th and 20th century rocket developments, leading to the emphasis on liquid propellant rocket engines. F. I. Ordway, III, cogently reviews the alleged claims of Pedro E. Paulet regarding liquid propellant rockets, and three Russian essays deal with Soviet rocketry of the 1930's and 1940's. Two of the papers in this section deal with F. A. Tsander, all the more interesting because Leonid S. Dushkin, one of Tsander's pupils, authored the selection on experimental work done by Tsander's followers, and co-authored the essay analysing Tsander's liquid propellant engine designs.

Among the memoir papers in Part III, Rudolf Nebel's recollections of his involvement in astronautics are brief but colourful, and two longer memoirs are particularly noteworthy. Frank J. Malina's contribution on rocket research at the California Institute of Technology between 1939 and 1946 details an era of siginificant American work, including JATO development and other programmes. Ernst A. Steinhoff's reminiscences on "Development of the German A-4 Guidance and Control System, 1939-1945," include historical insights and graceful recognition of many contributions.

The nine selections in Part IV include seven memoirs and two historical essays. The US Navy's early postwar efforts to develop an Earth Satellite are perceptively assessed in R. Carghill Hall's well-written paper, while a multi-authored study describes LH_2 work at Aerojet General Corporation under Navy contracts between 1944 and 1950. There is a long, informative memoir by C. Stark Draper on "The Evolution of Aerospace Guidance Technology at the Massachusetts Institute of Technology, 1935-1941," and an illuminating and thoughtful memoir by Frank J. Malina, concluding his review of the pioneering rocket research conducted at the California Institute of Technology between 1943 and 1946. Other notable memoirs in this last section include F. Zwicky's comments on astrophysics, William H. Pickering's and James H. Wilson's paper on the Jet Propulsion Laboratory, 1944-1958, and Robert R. Gilruth's reminiscences on missile research at the Wallops Island Missile Range as a prologue to the Mercury manned space programme.

It is regrettable to find a persistent, nagging number of typographical errors and mispelled words in these two volumes. It is also true, as the editor acknowledges in his preface, that these symposia papers are uneven in quality. But readers should not be discouraged. Both volumes include numerous illustrations of considerable interest, and many of the papers include references of considerable value. Considered as a whole, the publication of these historical symposia consistutes an important and useful contribution to the literature of aerospace history. It is an enterprise that should continue.

Dr. R. E. BILSTEIN

Members interested in preparing Reviews, particularly of technical works, are invited to write to the Executive Secretary.

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: Tel: 01-821 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor 12, Bessborough Gardens, London, SW1V 2JJ.

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

33rd Annual General Meeting

The 33rd Annual General Meeting of the Society will be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **22 June 1978** at 6.30 p.m. A detailed Agenda appeared in the April issue of *Spaceflight*.

Should the number of nominations exceed the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all members.

29th I.A.F. Congress

The 29th Congress of the International Astronautical Federation will be held in Dubrovnik, Yugoslavia, from **1-8 October 1978.**

Further details will be announced later.

Southern California Meeting

Theme **SPACE: TODAY'S HOPE, TOMORROW'S REALITY**

To be held in Los Angeles, California, USA late **September** – early **October 1978.** A Symposium in three parts:

Part 1 – Survival: Holding the Fort

Part 2 – Reconstruction: Spring Cleaning

Part 3 – Expansion: New Horizons

Offers of papers are invited. Further information is available from Mr. A. A. J. Hooke, M/S 114-122, Jet Propulsion Laboratory, 4800, Oak Grove Drive, Pasadena, Calif. 91103, USA.

Film Show

To be held in the Botany Lecture Theatre, University College, London, Gower Street, London, WC1 on **11 October 1978**, 6.30-8.30 p.m.

The programme will be as follows:

(a) Reading the Moon's Secrets
(b) Mercury, Exploration of a Planet
(c) HEAO, the New Universe
(d) Images of Life

Admission tickets are not required. Members may introduce guests.

Film Show

To be held in the Botany Lecture Theatre, University College London, Gower Street, London, WC1 on **15 November 1978**, 6.30-8.30 p.m.

The programme will be as follows:

(a) Remote Possibilities
(b) The Weather Watchers
(c) If One Today, Two Tomorrow
(d) Mercury, Exploration of a Planet (Repeat)

1978-9 PROGRAMME

The Society will operate a much-reduced Programme of Activities during the 1978/9 session, owing to the heavy commitment with the redevelopment of our new offices.

The full level of activities will recommence in September 1979, hopefully with a major portion held in our planned new Meetings Room.

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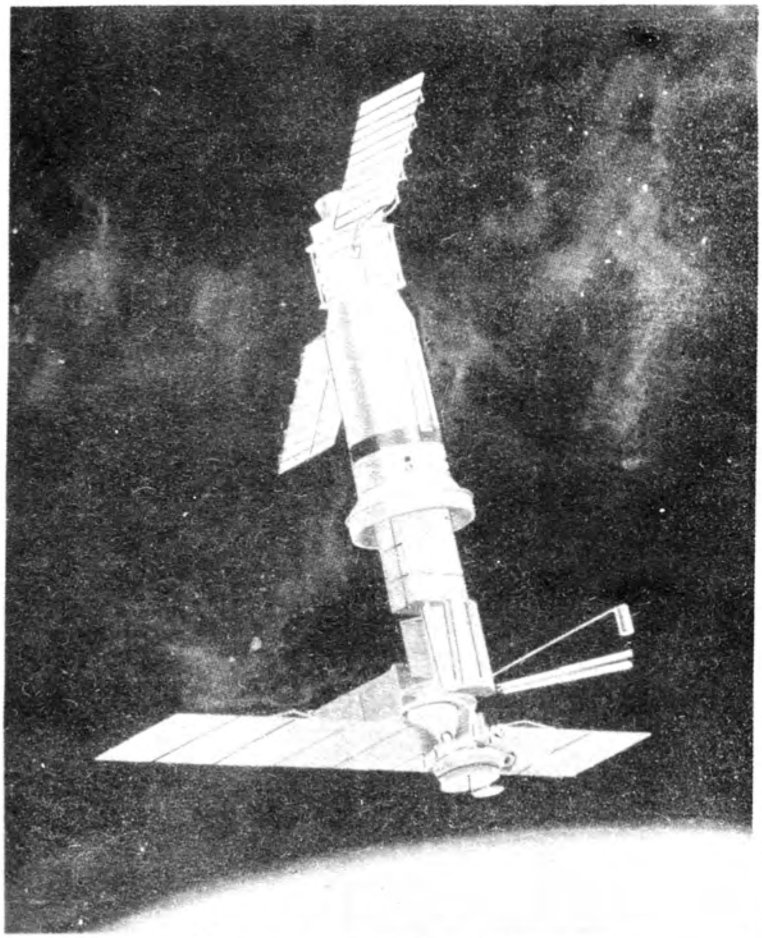

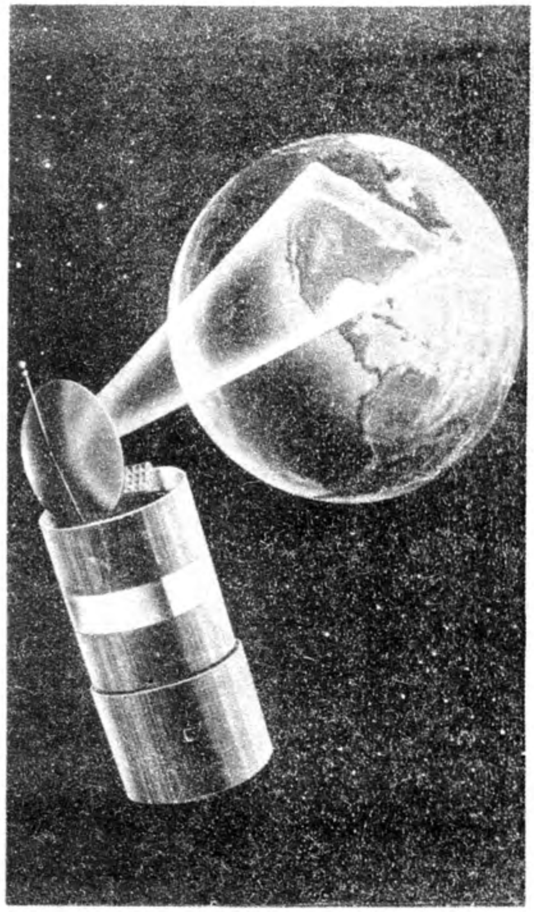

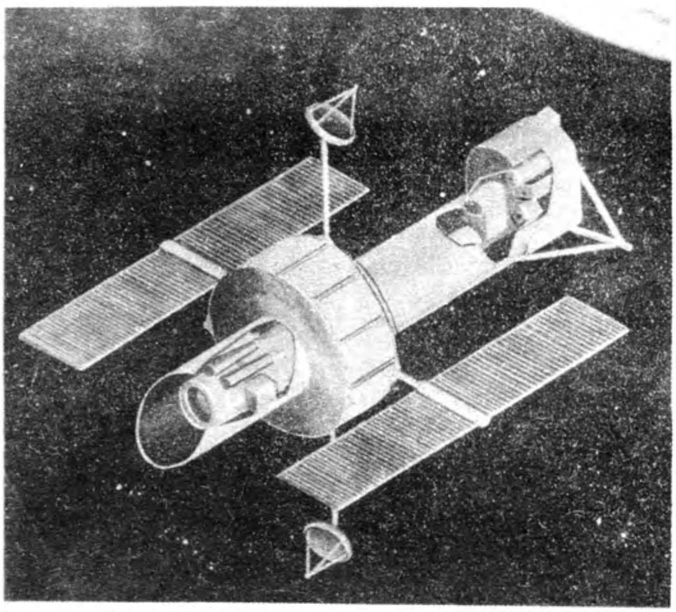

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CONTENTS

COVER

SATELLITE MISCELLANY. *Top,* NASA's new ocean surveying satellite Seasat 1. On-board instruments measure wave heights, provide radar images of waves and ice fields and measure surface winds and direction, and surface temperature. The spacecraft, which is based on the re-startable Agena rocket stage, embodies some of the technology of USAF reconnaissance satellites. Seasat was launched by Atlas F from Vandenberg AFB into a near-polar 497 mile (800 km) circular orbit. *Below,* proposed Earth-orbiting system known as the Advanced X-ray Astrophysics Facility (AXAF) under study at the Marshall Space Flight Center, Huntsville, Alabama. The long-lived X-ray observatory, approximately 42 ft (12.8 metres) in length and weighing some 20,000 lb (9,070 kg), is proposed for launch by the Space Shuttle in the mid-1980's. It would be capable of being repaired or retrieved in orbit. Scientific objectives include studies of stellar structure and evolution, large-scale galactic phenomena, the nature of active galaxies, rich clusters of galaxies and cosmology. *Right,* in the early 1980's Canada will use improved Anik domestic satellites to link long-distance communications along its vast southern land-mass coast-to-coast. Telesat Canada recently awarded Hughes Aircraft Company a $53.6 million contract to build three of the new spacecraft, Anik C, D and E, to keep pace with projected telecommunications demands of the next decade. The first is scheduled to be launched by the Space Shuttle in early 1981.

MILESTONES

May

12 ESA's ground station in Spain at Villafrance del Castillo, 30 km (18.6 miles) west of Madrid, is inaugurated by King Juan Carlos. Initially, the station will be used to monitor and control three major satellites: the International Ultra-violet Explorer (IUE) launched 26 January 1978; OTS 2 (Orbital Test Satellite) launched on 11 May 1978, and Marots, the maritime satellite to be launched 1980. Station has three antennae, one of 15 m (49.2 ft) diameter for IUE, one of 3 m (9.8 ft) diameter for OTS 2, and one 12 m dish for Marots. It is linked with the European Space Operations Centre (ESOC) at Darmstadt which also takes input from ESA stations in Redu, Belgium; Michelstadt, West Germany, and Fucino, Italy.

16 A light-weight pilotless aircraft with a 65 ft (19.8 m) wing span is proposed by Jet Propulsion Laboratory as part-payload of a future Mars exploration payload. The self-erecting aircraft, powered by a hydrazine-powered propeller, would fly at low altitude in the thin Martian air to reconnoitre the surface and return other science data. Payload 90-220 lb (40.8-99.8 kg); cruise range 2,500 miles (4,023 km).

16 Salyut 6 is manoeuvred upwards by Soviet mission control but new orbit is too elliptical for rendezvous and the ground track is not stabilised to give the usual alternate day launch windows. At least one orbital correction will be necessary before the next Soyuz launch. The new orbital parameters are 321 x 362 km, 51.63 deg, 91.30 min. Possibly the station has been put into a parking mode during a period of increased solar activity.

18 European Space Agency names three scientists to serve as Payload Specialists in support of first Spacelab mission scheduled December 1980:
Ulf Merbold, 37, a research scientist from West Germany.
Claude Nicollier, 34, an astronomer and pilot from Switzerland, and
Wubbo Ockels, 32, a physicist from the Netherlands.
Of the three people named as Payload Specialists, one will actually fly in space with one NASA Payload Specialist. The choice will be made "some months before the flight." The other two will act in a back-up role and will participate in ground-based mission activities carried out during the flight, at the Johnson Space Center. The three Europeans will be appointed to the staff of ESA and will be attached to the SPICE team (an ESA body responsible for Spacelab Payload Integration and Coordination in Europe) located in Porz-wahn, Germany. In July they begin a period of intensive training, in Europe and the United States, during which they will learn to operate the on-board experiments. On Spacelab's first mission, investigations will be conducted in stratospheric and upper atmosphere physics, materials processing, space plasma physics, life sciences, astronomy, solar physics, Earth observations and space technology. During the mission the Lab – operating within the cargo bay of the Space Shuttle Orbiter – will be orbiting at a distance of some 250 km (155 miles).

19 Soviets launch Cosmos 1009 from Tyuratam into orbit of 971 x 1,378 km by 66 deg inclination; period 109 minutes (according to *Novosti*). US Department of Defense describes mission as first test of new 'hunter-killer' satellite. Target was Cosmos 967, launched from Plesetsk 13 December 1977, which also served as target for hunter-killer test of 21 December 1977. Target was orbiting at 977 x 991 km x 65.8 deg; period 104.7 min. Interception was made at beginning of third

[Continued overleaf

orbit. According to NORAD data, Cosmos 1009 progressed from an initial orbit of 145 x 950 km x 65.2 deg to 965 x 1,384 km x 65.84. Following a close pass of the target, the interceptor re-entered the atmosphere over the Western Pacific. Believed to have been 15th anti-satellite test since programme began 19 May 1968.

19 Reported from Paris that France plans to launch an Earth resources satellite by the ESA Ariane rocket in 1983. Project is called SPOT (Systême Probatoire d'Observation de la Terre). Same basic 'bus' will be used for first French military reconnaissance satellite, Samro, which will return imagery *via* a radio/video link. Samro is expected to be launched about 1985.

20 West German OTRAG company launches second single-stage rocket with cluster of four motor tanks burning nitric acid and kerosene from launch site in the north of Shaba Province, Zaire. On this occasion launch was made from a tower to improve directional accuracy. For first time, two of four motors were cut off in flight to guide rocket to its planned target. The rocket, which burned for about six minutes, reached a height of some 30 km (18.6 miles) and travelled a similar distance. The first OTRAG launch on 17 May 1977 was limited to about 10 km (6.2 miles) altitude by partially filled tanks.

20 NASA launches 589 kg (1,300 lb) Pioneer Venus 1 by Atlas-Centaur from Cape Canaveral at 9.13 a.m. EDT (2.13 p.m. BST). Expected to swing into orbit round Venus on 4 December 1978 as orbiting weather station to send back temperature and pressure data, cloud cover pictures and radar images of surface. A second spacecraft, Pioneer Venus 2, to be launched 8 August, is expected to arrive on 9 December. Its main object is to eject four scientific probes into atmosphere of Venus.

21 Orbit of Salyut 6 space laboratory is now 319 x 352 km x 51. 6 deg; period 91 min, according to *Novosti*.

22 Launch of GEOS B now scheduled for 14 July may be further delayed because of slippage in Delta launch preparations at Cape Canaveral, according to NASA. The first attempt to orbit a GEOS in April 1977 was not a complete success because the launch vehicle delivered the satellite into an incorrect orbit. The satellite, which should have achieved geo-stationary orbit, worked perfectly in its lower but unsatisfactory elliptical orbit. The back up model, originally built to develop systems for GEOS, left the European Space Technology Centre at Noordwijk in the Netherlands in May *en-route* to the Cape. GEOS carries scientific experiments from 11 research institutes to study the magnetosphere from geostationary orbit. Responsible for the satellite is the European STAR consortium led by BAe Dynamics Group at Bristol.

22 Three Space Shuttle Main Engines in first major test firing achieve 15 second burn at NASA's National Space Technology Laboratories, Bay St. Louis, Miss. (Previous firing was a one-second ignition test on 21 April). "Everything went as planned" said Bob Lindstrom, Space Shuttle Projects Manager at MSFC. The engines reached 70 per cent of their rated thrust. Over the next several months, additional tests will increase the duration of firing and the engine thrust levels until they are fired at 109 per cent of rated thrust for about eight minutes at a time to simulate requirements of an actual space mission.

23 Cosmos 1010 is launched from Plesetsk into orbit of 218 x 257 km x 81.4 deg inclination to "continue the programme for exploring the Earth's natural resources." It has a period of about 89 min.

24 Indian Space Research Organisation (ISRO) reports that India's second satellite, designed to return "valuable information on natural resources, water reserves and other data of importance for the Indian economy," will be launched by the Soviet Union in September. First launch of nationally-developed SLV-3 four-stage solid propellant rocket will be made from Sriharikota Range north of Madras early next year. Launcher, which stands 19.4 metres tall and weighs 17.3 tons, is designed to place 40 kg into 1 400 km circular orbit.

25 NASA defers launch of GOES C at Cape Canaveral until 16 June because of delays incurred with the launch of OTS 2. Originally scheduled for 25 May and then 10 June, GOES C employs the Delta 2914 launcher. GOES C is the third of a family of Geostationary Operational Environment Satellites developed by NASA for the US National Oceanic and Atmospheric Administration (NOAA).

31 OTRAG team returns to Germany after successful test of low-cost rockets in Zaire. Lutz Kayser, company president, announces launch of two-stage test vehicle from Shaba using 16 motor tanks; says he expects to put a small payload into orbit "next year."

June

1 After tracking stations had made contact with Skylab in March and April, NASA prepares to effect series of attitude changes to establish control of the station and thereby extend its orbital life by 6 to 12 months to sometime between late 1979 and mid-1980. Manoeuvres will decrease atmospheric drag on the station by aligning its central axis with the flight path. Procedures involve putting a new program into the on-board computer, using the attitude control system to manoeuvre Skylab into the desired position and operating the control moment gyros to keep the station in that attitude. A successful attitude change manoeuvre could provide sufficient time to carry out a Skylab re-boost or controlled deorbit mission on an early Space Shuttle flight.

3 *Novosti* reveals that 'space alloys' – so called because the component metals cannot be mixed in the Earth's gravitational field – have been reproduced in the laboratory of the Latvian Institute of Physics. The effect of gravity was overcome by use of magnetic fields.

7-9 'Space and Civilisation' conference at the Palais des Congrès, Lyons, France, attracts contributions from ESA, CNES, NASA and the Soviet Academy of Sciences' Space Research Institute.

8 Talks between the Soviet Union and the United States open in Helsinki on possible agreement to ban the use of anti-satellite weapons.

8 Johnson Space Center Mission Control begins activating by remote control two gyros on board Skylab. Manoeuvre to stabilize the station was successfully concluded 10 June.

THE NEW LANDSAT

Introduction

On 5 March 1978 the National Aeronautics and Space Administration launched a new, improved satellite from the Western Test Range in California to monitor the Earth's natural resources. The 900-kg (1,980 lb.) Landsat 3 entered a 917 km (570 mile) circular, near polar orbit. Circling the globe every 102 minutes, its remote sensors view a 185 km (115 mile) wide strip of the Earth running nearly north-to-south at an angle to the equator of 99 deg.

In this type of orbit, surface coverage of the Earth proceeds westward, with a slight overlap, such that the globe is covered once every 18 days. The spacecraft's orbit is synchronous with the Sun. Thus Landsat 3 (like Landsat 2) crosses the equator at the same time (9:30 a.m. local time) every orbit. This results in consistent and constant lighting of Earth, the best condition for the spacecraft's imaging systems. Synoptic, repetitive coverage of Earth's surface under consistent observation conditions is required for maximum utilisation of the multispectral imagery.

Large-scale Perspective

The most common value attributed to the Landsat system is the large-scale perspective. Structural elements, perhaps irregular or even discontinuous within the confines of a smaller area, may be revealed as regional or even semi-continental in extent.

Another major asset is the system's repetitive observation which makes possible the detection of short-period changes – as frequently as every nine days using two satellites.

Most Important Data Uses

The three most important potential uses of the Landsat data identified so far correspond to three of the major problems confronting the world today. These are energy supplies, food production and global large-scale environmental monitoring.

Innovations in the Landsat-3 multispectral scanner system (MSS) provide for the detection of temperature differences in vegetation, bodies of water and urban areas – day or night.

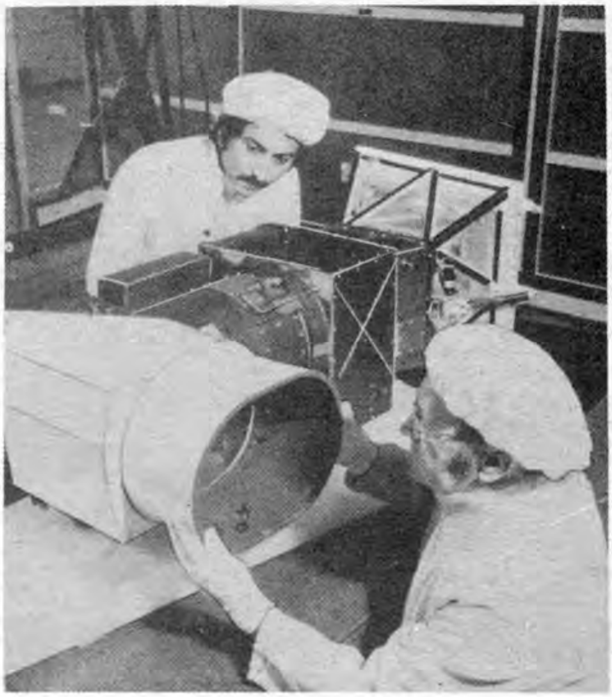
Improvements in the return beam vidicom (RBV) sensor has increased the resolution of its recorded images by 50 per cent. Thus, areas as small as half an acre – about two urban house lots – can be identified and studied.

In addition to its two major remote sensing systems, the Landsat 3 carries a data collection system (DCS). This versatile experiment collects radioed data directly from as many as 1,000 remote ground platforms and relays them to a Landsat data acquisition station. Volcano activity, stream flow, water and snow depth, water temperature and sediment density are some of the measurements collected.

Secondary Payloads

Landsat 3 was launched from the Western Test Range (WTR) aboard a two-stage Delta launch vehicle. In addition to Landsat 3, riding piggyback aboard the rocket was an amateur radio communications satellite, OSCAR-D. This satellite is being used by amateur radio buffs around the globe for a variety of purposes, particularly with small fixed and mobile stations. Primary emphasis is placed on its application as a teaching aid in secondary schools.

Another experiment attached to the second stage of the expendable Delta rocket is a unit to help designers of future space systems. This unit, called the Plasma Interaction Experiment (PIX), will remain in orbit at an altitude lower than either the Landsat 3 or the OSCAR-D. It is designed to provide information on how to control detrimental interactions between high voltage systems and the electrically charged plasma fields in space.



HEAT SCANNER. America's latest Earth resources satellite, Landsat 3, launched on 5 March scans the Earth around the clock providing scientists with information on energy sources, thermal water pollution, temperature variations and ocean currents. The Hughes Aircraft multispectral scanner (shown here) produces infrared pictures night and day, which are sent in electronic form to Earth for processing. The technician is examining the instrument's aperture which contains reflective mirror and telescopic optics.

Hughes Aircraft Company

The Landsat sensors are improved versions of the MSS and the RBV units carried by the two earlier Landsats. All three satellites carry the same DCS experiment.

The improved sensors on Landsat 3 supply data significantly improved over those used in the proven application of Landsats 1 and 2. In agriculture, for instance, the added thermal infrared channel on the MSS is the major improvement. The thermal data provides information on plant stress, vigour and other changes characterised by temperature differences. The improved resolution RBV system provides more accurate measurements of agricultural fields to improve the crop yield projection.

NASA's research programme is being geared to assess the value of these improved data sources as well as to incorporate their information content in the current operational applications of Landsat data by other federal, state and industrial users.

In providing more accurate discrimination between suburban areas and surrounding rural or farm lands (important for census studies) the improved Landsat 3 will increase researchers ability to recognise "heat islands" associated

with urban and industrial developments; it also will permit improved monitoring of thermal sources such as mine fires and power plant effluents.

Ground Stations

Three NASA tracking and data acquisition facilities are equipped to receive sensor data from the Landsat spacecraft. The Landsat facilities at Goldstone, California, and at Goddard Space Flight Center, Greenbelt, Maryland, can receive sensor and DCS data directly from the spacecraft whenever it is in direct line-of-sight. The primary station at Fairbanks, Alaska, collects such data by commanding the satellite's tape recorders to replay during each orbit over the North Pole area.

International interest in Earth resources remote sensing is widespread and growing. Foreign-funded ground stations are now operating in Brazil, Italy and Canada (two facilities). Another station is under construction in Iran and others are being planned by Argentina, Chile, India and Zaire. Australia, Japan and Sweden are among other countries presently considering such an investment.

Landsat ground stations cost the host country some $4 to $7 million to establish and from $1 to $2 million per year to operate. In addition, countries operating these stations are paying the U.S. $200,000 per station a year as of July 1976. This charge was established by NASA to assist in defraying the cost for the space segment. Data from foreign stations is distributed directly by the organisations operating the stations.

Once Landsat data received in the U.S. is processed at Goddard Center, copies are forwarded to the Department of Interior's Earth Resources Observation Systems (EROS) Data Center at Sioux Falls, South Dakota. On receipt at Sioux Falls, data are in the public domain and copies can be purchased by anyone.

The overall Landsat programme is the responsibility of NASA's Office of Space and Terrestrial Applications, Washington D. C.

Project management for the Landsat spacecraft, the Delta launch vehicle, the NASA Image Processing Facility and the worldwide tracking network rests with the Goddard Center.

General Electric Company, Space Division, Valley Forge, Pennsylvania, is the prime contractor for the Landsat spacecraft, the data collection system and wideband video tape recorders aboard the spacecraft and the ground data handling system at Goddard.

Hughes Aircraft Company, Space and Communications Group, El Segundo, California, is the prime contractor for the multispectral scanner; and RCA, Astro-Electronics, Princeton, New Jersey, is prime contractor for the return beam vidicon camera. The McDonnell Douglas Astronautics Company, Huntingdon Beach, California is prime contractor for the Delta launch vehicle.

NASA costs for the Landsat programme are about $251 million. This includes $149 million for three spacecraft and their instruments, $54 million for the data handling facility at Goddard Center and ground operations, $34 million for support of investigations and about $14 million for three launch vehicles.

Landsat Usage to Date

Images produced by the sensors onboard Landsats 1 and 2 have been subjected to intensive study and experimentation by hundreds of scientists in a broad range of disciplines. Many of these scientists, located throughout the United States and 52 other countries, were selected by NASA for formal sponsorship as principal investigators. This was done to induce systematic examinations of Landsat's potential value as a new tool in remote sensing.

The areas studied include agriculture, rangelands, forestry, water resources, environmental and marine resources, cartography, land use, demography and geologic survey and mineral/petroleum exploration.

2.

GLOBAL MAPPER. These new high-resolution TV cameras aboard Landsat 3 take pictures of the Earth in 50 by 50 square mile (130 square kilometre) frames. High quality maps can then be produced of remote regions of the Earth never before mapped in such accurate detail. The camera – built for NASA by RCA Astro-Electronics, Princeton, New Jersey – are seen being inspected by RCA Program Manager Bert Soltoff.

National Aeronautics and Space Administration

The volumes of scientific and technical literature on Landsat studies primarily address techniques of processing, analysis and interpretation. A limited number of quasi-operational projects also were undertaken.

Based on the research results to date, the following sections describe the current assessment of what Landsat multispectral data can be made to reveal, the extent to which these data respond to data requirements and the uses of these data.

Agriculture

Worldwide preoccupation with the food supply problem has focussed strong attention on the contribution of space remote sensing to better management of agricultural systems and more timely information on output of key agricultural commodities.

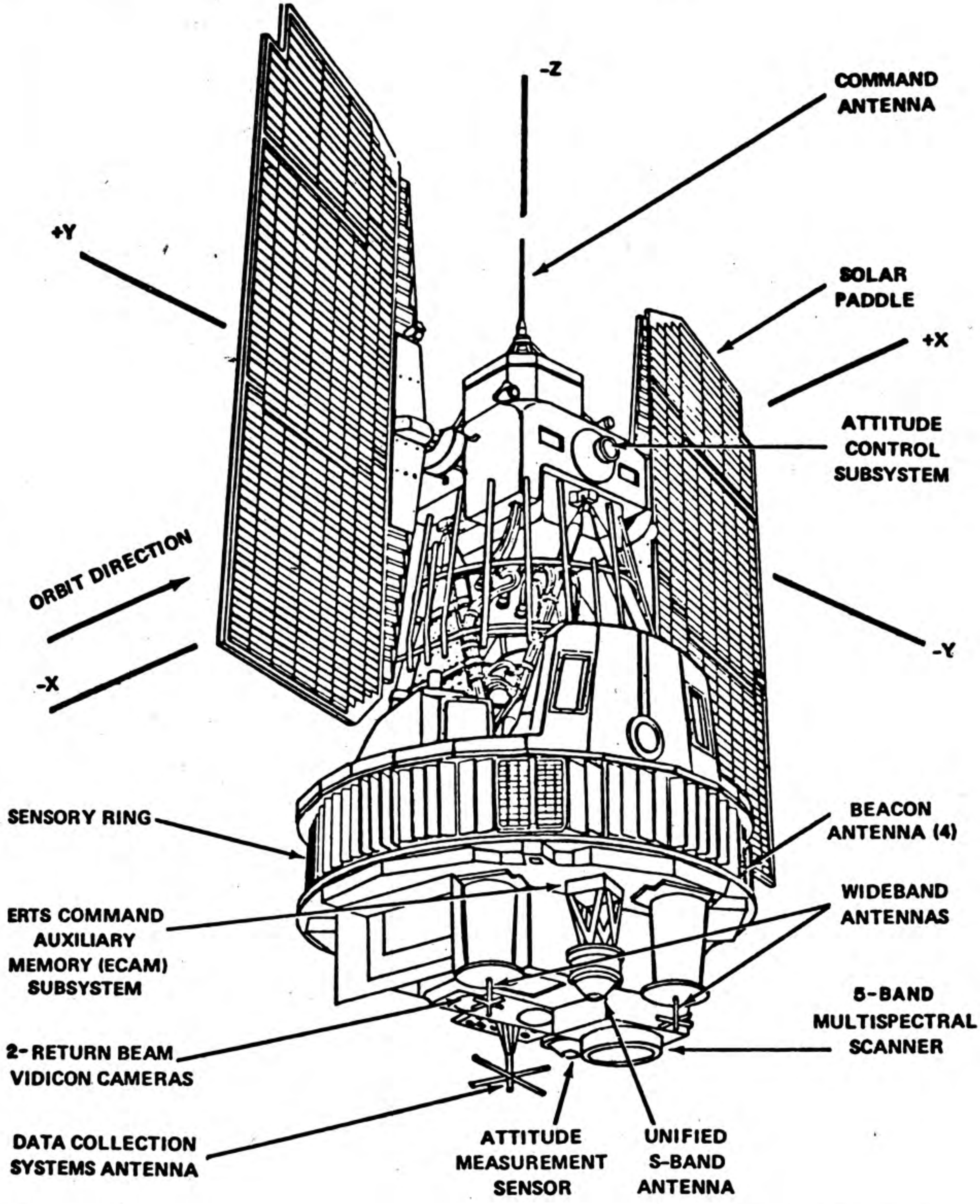
Investigations of the application of satellite sensing to U.S. agriculture have dealt principally with the inventory of crop acreage, forecasting of crop yield and soil survey.

Large Area Crop Inventory Experiment (LACIE)

The large Area Crop Inventory Experiment (LACIE) has been a major technological effort to determine how Landsat data can be used to monitor situations of major national or global importance. LACIE has been a three-year, joint experiment of USDA, NASA and NOAA to determine if foreign commodity production (wheat has been used as the example) can be forecast with an accuracy of 90 per cent, nine years our of ten. The third crop year, 1976-1977, has been completed and a final report on the three-year period is being compiled.

So far, LACIE has shown that when field sizes are large enough to be compatible with the resolution of Landsat data the results are compatible with the 90 per cent accuracy goal and the desired confidence goal.

Since the LACIE goal is stated in production terms, both acreage and yield components must be determined. While the acreage component has been determined from Landsat data, NOAA has led the effort to determine yield by using



Landsat 3. *National Aeronautics and Space Administration*

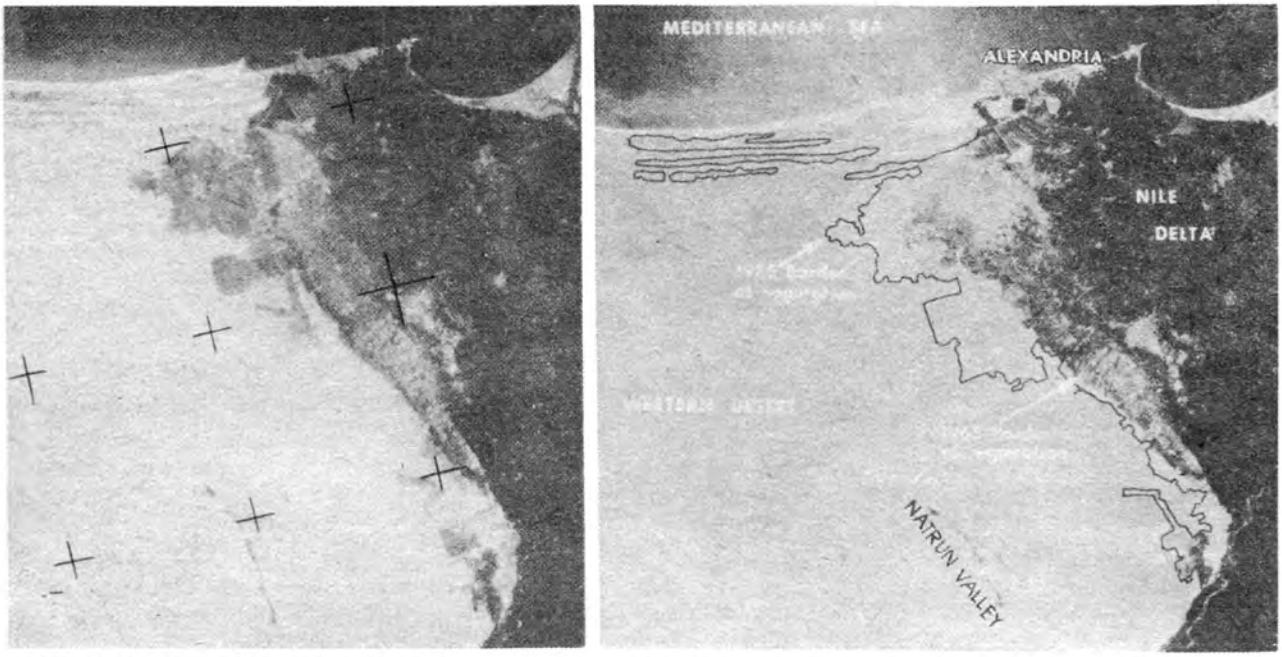
World Meteorological Organization (WMO) weather information. The WMO data has been compared with meteorological satellite data to determine the real extent of the existing weather situation.

Better area determination is required where small fields predominate and better yield modelling is required, but the results of LACIE to date have been sufficiently promising for the USDA to want to expand the experiment to include more commodities and more crops situations.

NASA, NOAA and USDA are presently involved in a fourth year of experimentation and are planning for an increased research effort to determine how remote sensing information can help meet more broadly defined agricultural information needs.

Soil Survey

Studies to determine whether Landsat data could provide useful soil and land system surveys also have been en-



DESERT RECLAMATION. Increase in area of vegetation just west of the Nile Delta in photograph taken during 1975 Apollo-Soyuz mission, compared with Gemini 5 photo of same region (inked-in lines) obtained some 10 years earlier. Such findings are important to a country like Egypt, which is four per cent fertile land and 96 per cent desert.

National Aeronautics and Space Administration

couraging. Variations in soil characteristics can be identified in computer-enhanced Landsat imagery. Delineation of these patterns, confirmed by ground observation, can yield soil association maps which provide a good identification of probable soil characteristics.

Cooperative studies between soil scientists of the USDA Soil Conservation Service and scientists in universities have shown in Indiana and Missouri that digital processing of Landsat data provides sufficient information for detailed mapping of soils at scales of 1:15,840 and 1:20,000. These studies also showed that, in some cases, specific types of soil can be identified.

Spectral maps produced from Landsat data have provided important differences between soils not discernible in conventional black-and-white photographs. With a spectral map of a county prior to field sampling and measurement, a soil surveyor can determine quickly locations and a real extent of soils with significant differences. Such information can greatly reduce the number of observations and time required in the field.

Significant use of Landsat imagery is foreseen for land and soil reconnaissance level surveys in the developing world. In a project now underway in Tanzania, digitally enhanced Landsat imagery has been used with ground and aircraft observations to provide a basic land system evaluation of the Arusha district at a scale of 1:250,000.

The soil survey staff of the United Nation's Food and Agricultural Organisation is now utilising Landsat data in a world wide study of soil limitations for agricultural production.

Rangelands

Rangeland monitoring studies are conducted to gather information needed to improve productivity. They seek data on range conditions, trends, readiness for grazing and patterns of grazing use.

Investigations in the U.S. to determine the value of remote sensing from satellites for rangeland management have focussed on three concerns: inventories of range vegetation types, evaluation of rangefeed and monitoring of rangeland improvement and change.

Landsat has produced useful rangeland inventory data in the U.S. despite the fact that not all range types show up clearly to the satellite's sensors. Low plant density, variable plant composition and the low percentage of ground cover all pose problems for remote sensors.

Dynamic sensing from Landsat of the annual grasses which cover most of the foothill terrain in California has traced the greening of the landscape with the onset of the rainy season each fall and winter and the progressive browning with the onset of the dry season in the spring and summer Such information may help recognise potential fire hazard, project the anticipated weight gain of livestock and determine the extent to which drought and grazing have reduced available forage.

In one study, rangeland features such as meadows, springs, moist sites, islands of browse, ponded water and small reservoirs – as small as 1-1/2 acres in size – were detected by using Landsat data and manual analysis techniques. These features in rangeland environments are sensitive "areas" that need to be monitored in order to permit assessment of associated grazing, wildlife and recreational potential of the broader area.

Beside identifying existing or potential rangeland areas that require more detailed aerial or ground observation, a system of rangeland monitoring from space can help to guide a number of important decisions in developing countries:

- Timing of turnout and removal of livestock in grazing areas;
- Preparation of plans to prevent overgrazing and to open up new areas for grazing;
- Timely measures to reduce fire hazards;
- Additional investment in range improvements by draining, irrigating, seeding or fertilizing.

A study in the Arusha region of Tanzania employed Landsat data successfully in delineating boundaries for 550 distinct landscape units in an area measuring 82,000 square km (32,000 square miles) on the basis of landform and vegetation characteristics. Fourteen grassland types of varying suitability for forage were recognised in the Landsat data. These delineations, fortified with detailed sampling information provided by aerial photography and on-site inspections, have identified promising areas for range, agricultural and ground water development.

Forestry

The research findings of various investigators indicate that Landsat data could contribute to forest management and help to reduce forest inventory costs. The data have pro proved useful with respect to:

- Sampling procedures for estimating volume of timber;
- Monitoring of forest cutting of clear-cut-type;
- Mapping of forest fire burns, especially the "crown fire" type common in the western part of North America.

Quasi-operational studies in northern California found that Landsat data, with the aid of multistage sampling, were able to provide timely and cost-effective inventories of gross timber volume and an economical inventory of total timber resources, including the factors of growth rate and timber stand condition. Manual and automatic techniques of data analysis used in the same studies detected changes in the resource base over time, assisting location and area estimation of harvesting activities, post-fire mapping and fire damage assessment.

A Canadian project using Landsat imagery to map forest burns in Saskatchewan detected 42 burns across the northern part of the province. The Landsat imagery was produced far more quickly and accurately than would have been possible for photographic imagery obtained from conventional helicopter or aircraft platforms.

In most of the developing world, data on forest resources are crude and incomplete at best. There are no comprehensive systems of forest inventory by aerial photography of the type found in the United States and in other technologically advanced countries.

But data requirement may also be substantially less stringent. In such a setting, Landsat data may be of significant benefit in providing basic information on the extent and location of forest resources and the changes occurring in the woodlands.

Developing countries are increasingly aware of the need to manage their forest resources not only to meet their timber and energy needs but also to preserve the ecological balance and to prevent erosion,siltation of dams and pollution of coastal waters. Mapping of forest vegetation, estimation of timber volume and measurement of the rate of depletion – to which satellite data can make important contributions – are essential steps in the planning of control measures.

In Brazil, Landsat imagery has been used to monitor a programme for controlled development of large areas of the Amazon forest for various purposes, especially cattle grazing. Landowners, with the help of government subsidies, are permitted to cut down trees up to a third of their land holdings. Routine and systematic use of Landsat imagery has proved to be the only economic way of enforcing the terms of the government-assistance contracts and of monitoring and controlling the volume of tree-cutting.

Water Resources

Surface Water

Landsat data have been found to be particularly reliable in locating surface water. One multispectral channel (Band 7 on the MSS) shows the contrast between water and other surfaces on the ground so clearly that water bodies larger than 10 acres can be identified with 99 per cent accuracy. With the help of computer programs, it is now possible to compile maps showing surface water areas larger than about six acres for most countries of the world.

For areas lacking adequate drainage maps, Landsat in many cases can provide data on stream networks to within a few per cent of those displayed on topographic maps. In some cases Landsat alone cannot provide acceptable data, but in conjunction with topographic maps showing basin boundaries it can give relevant information on land use and vegetation for water resources management with better quality less cost and more frequency that can be obtained from other sources.

Landsat imagery can be used to assess major watershed characteristics that affect runoff. In a 1973 experiment, significant correlations were obtained between integrated basis reflectance values from Landsat and actual watershed conditions and runoff amounts in areas of dormant vegetation and dry conditions in Oklahoma. This suggests that it would be feasible, in semiarid to arid watersheds in developing countries, to develop much needed information for runoff prediction based on data from Landsat and available meteorological satellites. Recent studies in Colombia and Venezuela have indicated the value of data from synchronous meteorological satellites for improved runoff prediction and efficient, economical siting of hydro-meteorological stations.

Many studies in the United States as well as in several other countries have demonstrated the effective use of Landsat data for delineating flood areas, as least in large drainage systems where the floods lasted long enough to be observed on an 18-day cycle operated by Landsat or where trace of their past presence can be noted. For example, flooded cropland in the Indus Basin in Pakistan was distinguished easily by the satellite data from flooded semiarid areas and arid desert.

In many parts of the world, water availability stems from snowmelt. Landsat has shown a capability of measuring snowline and extent of snow within 5 per cent of the accuracy obtained by aircraft measurement or other means. The average of snow cover, multiplied by its depth and density, represents the storage of water that may be available for water supply, hydropower generation, navigation and irrigation, or that could be released suddenly to cause floods downstream.

Landsat has been able to provide reconnaissance-level data needed for the design and operation of large scale irrigation projects and for the design of a major impoundment structure. Studies based on Landsat data have produced significant results as input to water-demand and groundwater-flow models in Kern County, California. These studies of a desert region have identified crop areas to within 1 per cent of the aircraft census with acceptable levels of crop identification. Landsat data are now regularly used as an important factor in the water supply/demand assessment for that region.

Subsurface Water

Geologic information relating to groundwater may be derived from data obtained by multispectral sensors.

Landsat data can offer information on surface lithology, fracture patterns and vegetation and geomorphic indicators of shallow aquifers. Such information, properly interpreted, can serve as an exploration base and strategy for groundwater prospecting. Recent studies have shown that the information

SPACE 'EYE' ON LAKE OKEECHOBEE. The high-resolution cameras aboard Landsat 3 'snapped' this image of Florida's Lake Okeechobee on 14 March 1978. Some other features include Kissimmee River dumping into the lake (lower centre), Miami Canal (right centre), St. Lucie Canal (top left), and North River Canal, route 27 running in parallel with it (right centre). The rectangular fields southeast of the Lake are irrigated fields. Photo covers an area 50 by 50 miles (80 by 80 km).

NASA

is useful is siting shallow wells and thus may provide a cost-effective tool for improving groundwater exploration in semiarid lands. Landsat imagery has led to the identification of alluvial fans which may contain very large groundwater reservoirs. An alluvial fan about half as big as the state of Iowa has been identified in Landsat images of Western Brazil.

Two series of Landsat images taken five weeks apart made an important contribution to a multi-stage study of the annual flooding of the Lower Magdalena-Cauca River Basin in northern Colombia. The sequential images made possible a classification of the river marginal lakes according to their role in tempering the water wave and their potential for serving as reservoir basins. The Landsat imagery was particularly successful in identifying the lakes that dried up in the five-week interval. The Landsat data, together with aerial photographs and side-looking airborne radar (SLAR) images, yielded information needed by the governmental planners to determine the most practical means to reclaim land in the lower part of the inundated area.

Environmental Marine Resources

The Landsat has proven of value in recognising discontinuities of colouration in water and to distinguish differences in land cover over large areas for identifying certain types of pollution or environmental degradation. Colouration differences seen in Landsat imagery have led to detection of oil slicks and oil seepage in coastal areas, effluents carrying industrial or municipal wastes and water currents causing siltation. The effects of tin mining in shallow water along the coasts of Malaysia have been mapped with the help of Landsat data, which are also being used in a United Nations study of the environmental effects on land of strip mining of tin in that country.

Landsat imagery is being used experimentally to monitor strip-mined areas in the Appalachian region and in Idaho, to observe land deterioration in arid areas such as the Sahel and to measure the extent of damage of forest fires and floods.

In studies of sand seas, scientists have relied heavily on Landsat data to establish a basis for classsifying and monitoring environmental changes in the principal desert areas of the globe.

Landsat imagery is increasingly employed in analyses of coastal areas, especially where effluents and shallow waters differ in colour or reflectance from the local waters and are, therefore, readily identified and delimited. This information is applicable to problems of environmental protection, navigation and fisheries. Oil spills and seeps, illegal dumping and polluting effluents have been observed, both in shallow water and in adjoining wetlands. Certain fish stocks may also be located by identifying their habitats on the imagery. Navigation channels and inlets can be watched for changes in depths that may endanger shipping and boating. Repetitive coverage in coastal areas may be useful in determining major changes in rates of pollution, desimentation, erosion, marsh drying or subsidence.

In Gambia, Landsat imagery showed clearly that the currents from the Gambia River, carrying effluents from the city of Banjul, for some portion of the year swing past the beach frontage for which a tourist development project was planned with financing from the World Bank. New planning studies have had to take this factor into account.

Landsat also disclosed offshore pollution problems at two coastal tourist development sites in Turkey.

Cartography

The Landsat multispectral scanner has shown capabilities for cartographic mapping greatly exceeding original expectations. MSS imagery has several characteristics that enable it to contribute significantly to small-scale cartography in the United States and to become probably the most efficient current means of portraying the face of the land. These characteristics include:

- Uniformity of view over a wide area;
- Near vertical angle;
- Geometric and radiometric fidelity;
- Superior definition of certain natural features;
- Capacity to be turned into a finished map product very near to the "real time" of the acquisitions of the data.

Landsat imagery is helping to correct and update certain features of existing U.S. maps at scales of 1:250,000 or smaller at, or near, national map accuracy standards. With multispectral imagery it is possible to make 1:250,000 photo map overprints to fit with previous black-line data of conventional maps. The fresh information in the overprint has made it possible to observe such developments as urban sprawl and modifications to transportation networks. Using Landsat imagery and new mosaicing techniques, the U.S. Geological Survey has produced a new map of Florida which is the first colour musaic map form that maintains uniformly high image quality.

A new type of small-scale map has been made possible by the unique capacity of Landsat Band 7 to delineate land-water boundaries. This band can define water bodies as small as 200 m (656 ft.) in diameter with high reliability and can identify streams 20 to 50 m (65 to 165 ft.) wide if they are not over-hung by trees. The capability is expecially important for updating charts of estuaries in coastal areas and for outlining interior lakes.

Sensors on current Landsats are able to penetrate clear water surfaces to a depth of about 20 m (65 ft.). In the Caribbean, Landsat data made possible the charting of shallow underwater features that were previously unknown.

Cartographers have found that the Landsat scanners can produce with virtually no distortion, a generally continuous image on a defined map projection. Thus the Landsat series, with their uniform repetitive coverage, may provide the basis for an "automated" image-mapping system of the entire Earth.

For developing countries, the value of Landsat for cartographic purposes promises to be very high. More than half the geographic areas of Asia, Africa, and Latin America have not yet been mapped at scales larger than 1:1,000,000 and many of the base maps for the other areas are outdated.

With Landsat data, uncharted areas can now be quickly and cheaply mapped, existing maps can be updated with

CAPE CANAVERAL, FLORIDA. This Landsat 3 photo was taken on 14 March 1978 from an altitude of 570 miles (917 km). The launch pads along the Atlantic coast can be identified from the maps published in *Spaceflight*, March 1978, pp. 93 and 95. Clearly visible are the Apollo pads (upper left), Shuttle Transportation System runway (far upper left), and several causeways crossing the Banana and Indian Rivers. The bridge in upper left connecting the Kennedy Space Center to the mainland appears to be open to let large ships through. The white dots in the Banana and Indian Rivers are thought to be channel markers. Other notable features include the towns of Cocoa Beach, Merritt Island and Cocoa (centre to left of centre) and Port Canaveral (adjacent to Cape Canaveral).

NASA

acceptable accuracy and decisions can easily be made regarding areas where higher resolution imagery from aircraft is required. Several South American countries are currently using Landsat imagery to revise their small-scale and intermediate-scale maps.

Bolivia, with sizeable parts of its territory still inadequately mapped, is now using Landsat imagery to help fill the gap. A map at the scale of 1:1,000,000 of the entire country has already been updated and published. A more detailed map at 1:500,000 of the Coipasa area, meeting U.S. National Map Accuracy Standards, has also been published. Landsat data made possible the first geomorphological map of the country and contributed corrections to a recently published tectonic map. Maps are now being produced at a scale of 1:250,000 will serve as a basis for an inventory of Bolivia's natural resources including soil, forests and promising areas for mineral and petroleum exploration. With Landsat data, a task that was expected to take eight years, will now be accomplished in two.

Developing countries also have need for frequent updating of charts with respect to geographic features subject to change. For example, the temporal and spectral characteristic of Landsat are of exceptional value in defining land-water boundaries in countries with large deltas (Egypt, Bangladesh, Iran) or with shallow, interior drainage basin lakes (Iran).

Land Use

Landsat imagery has proven useful for regional planning purposes and the monitoring of land conversion along the urban fringe. However, urban planners, concerned with the disposition and relationships of small spatial units characteristic of the cityspace, generally require very high resolution imagery of the sort obtainable at present only from aerial photography.

State and regional planners, on the other hand, are interested in frequent updating of broader scale changes in the nature of land cover – such as the extent to which agricultural land is giving way to housing or the pace at which forest land is being depleted.

The level of accuracy obtained in the United States from Landsat is distinguishing among major categories such as forests, water and urban areas has been generally an adequate 90 per cent or better. Except for urban and built-up areas, more detailed categories (which distinguish, for example, between deciduous and evergreen trees) have been generally identified at an accuracy of 80 to 85 per cent. In some studies, imagery taken at different seasons has been digitally merged and has led to greater accuracy in identification.

For present land use purposes, satellite data can be a useful complement to photographic studies from aircraft platforms. For regional planning in particular, a satellite "scene" can serve as a reconnaissance base on which planners can pinpoint areas of stress or of rapid change for which more detailed information is required and can be obtained by aerial photography.

It is anticipated that Earth resource satellites will play an expanding role in providing periodic updates to data bases originally derived from standard mapping techniques. For the first time planners have a land use data acquisition system which can be continually revised at a level of accuracy commensurate with the accuracy of statistical updates developed for population and economic data between the decennial censuses. The computer processing of Landsat tapes permits incorporation of such data in data banks, whose use is rapidly increasing, and in which social, economic and resource information from a variety of sources is retrievable in relation to specific localities.

Resource planners in several state governments in the United States are beginning to use Landsat data in large-area transportation, recreation and environmental planning.

A substantial volume of land-use information was obtained from a comparative analysis of two sets of Landsat scenes covering the state of Orissa in India. One set was taken during the dry season and the other was recorded at the end of the monsoon.

The two sets of scenes highlighted the differences between dry and wet season agricultural patterns and were used to identify promising areas for conversion to irrigated two-crop production.

These Landsat data also indicated areas suitable for dams or barrages, showed the extent of forest cutting in the highlands and coastal regions and provided a new base for checking the accuracy of crop acreage estimates done by conventional means. They further showed the changing course of the Mahandi River and its tributaries from the time of the last topographic mapping two or three decades earlier as well as major changes in sandbars and coastal islands.

Demography

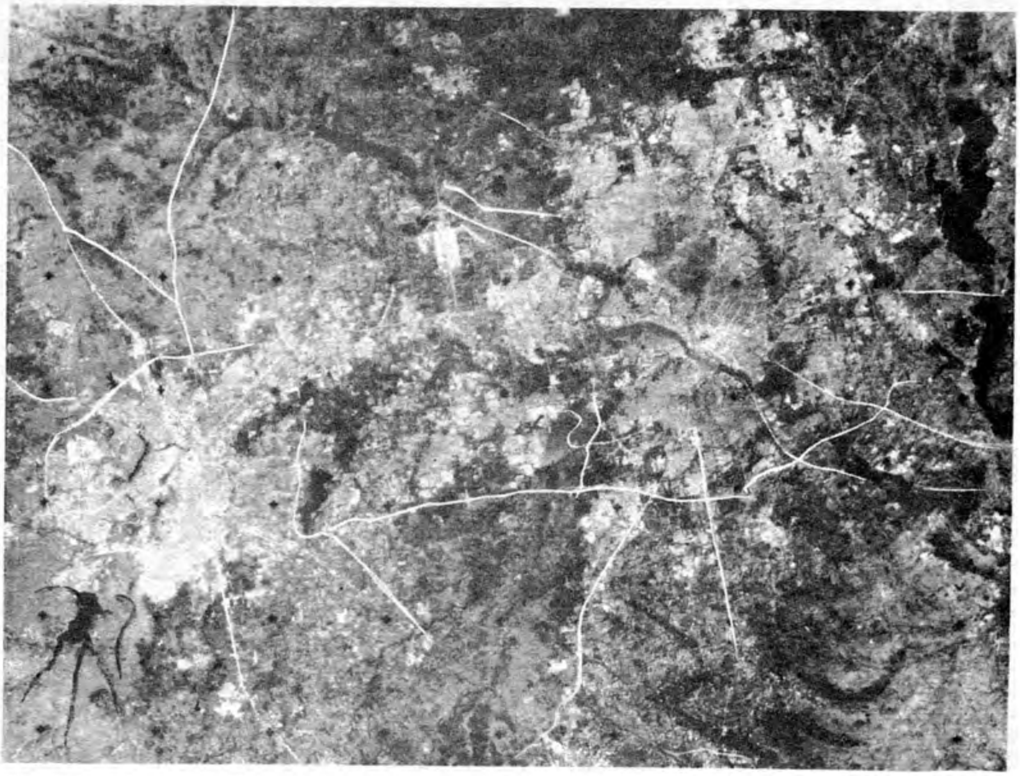
In the United States, demographic applications of Landsat data have been studied under the general heading of land use investigations. To the extent that urban classification categories can be identified, a population density can be assigned to each category on the basis of careful ground sampling. The U.S. Bureau of the Census is working with digital data from Landsats to test the validity of this application. Present Landsat data are useful for identifying new urban areas and drawing urban/rural boundaries. It is generally assumed that better spatial resolution will be needed for reliable classification of urban categories.

In many developing countries, the problem in demographic census is not only to gauge increments to urban growth but to determine the number, location and population density of old and new villages. Since most village settlements cover more than one acre (the approximate size of the individual pixel that registers on a Landsat sensor up to now), satellite data may provide a better case for estimating rural population in countries where compact villages are common than any enumerating system thus far employed. In countries in which rural population is more dispersed, Landsat data can provide information on patterns of land use from which it may be possible to infer population density with some accuracy. Studies to develop appropriate sampling techniques have been undertaken in several countries in Asia and Africa. Preliminary results appear to be promising.

In studies financed by Agency for International Development in Bolivia and Kenya, the U.S. Census Bureau is seeking to determine in what ways Landsat imagery may be applied in demographic census and sample survey operations and in population estimates based on village measurements and land use interpretations. The study in Bolivia was in progress before, during and after a nationwide census undertaken by the national governement. The timely coincidence of the study and the census makes it possible to test the value of Landsat data for precensus preparatory work and postcensus checking for accuracy.

Geologic Survey and Mineral and Petroleum Exploration

One of the most valuable attributes of satellite data for geologic application derives simply from the area covered by a single observation or photograph. A few Landsat frames can cover whole mountain ranges. It requires about 500 frames to cover the U.S. continent. As a result Landsat images provide a view of the geologic fabric of continents which is compatible with the scale of modern theories of global or plate tectonics. Structural elements, perhaps irregular or even discontinuous within the confines of a smaller area, may be revealed as lineaments of regional or even semi-continental extent, and prominent rock units may be traceable far beyond the site of initial recognition.



FT. WORTH – DALLAS. This photo was taken by the Landsat 3 Return Beam Vidicon TV camera on 27 March 1978. Notable landmarks are: Dallas, large whitish area at upper right; Ft. Worth, left centre, Dallas-Ft. Worth Airport, upper centre; Carswell Air Force Base, left of Ft. Worth; Love Field, north-west area of Dallas; Benbrook lake, south west of Ft. Worth; Lake Worth, north west edge of Ft. Worth; Eagle Mountain Lake, north of Lake Worth, and Lake Hubbard, north east of Dallas.

NASA

Geologists can follow such features across an entire fold belt without trying to piece together a multitude of photographs which differ in scale, exposure, light angle and quality of print.

Observations from space have two practical applications: improved geologic mapping and more efficient resource exploration. Good geologic maps are essential for the proper siting of major construction projects including railroads, highways, dams and power plants. Even in the United States, satellite data have been able to contribute to the accuracy and completeness of existing geologic maps and to identify faults hitherto unperceived.

A contribution of the U.S. Geological Survey to the 35-nation Circum-Pacific Map Project demonstrated the value of Landsat data for evaluating the accuracy of existing geologic maps and for augmenting map detail.

In some developing countries, national or regional geologic maps have been produced with the help of Landsat imagery far more quickly and efficiently than could have been accomplished by usual means and now provide a good basis for locational planning of development projects.

For site location decisions, however, satellite data on the geology, topography and hydrology of a region must be complemented by more detailed data obtained by conventional methods – aerial photography and ground observation studies.

Landsat has made it possible, for instance, to obtain synoptic and virtually distortion free images of high-relief mountain provinces in the Himalayas, the Alps and the Andean Cordillera. Such images help increase understanding of mineral genesis.

Location of major geologic elements generally will serve as a guide to selection of smaller targets worthy of closer study as possible resource areas, particularly if the interpretation is done by a trained observer familiar with the region. These smaller target areas can be further limited by image enhancement and/or computer analysis of multispectral data, with consequent reduction in the amount of costly and time consuming ground search. Further sophistication can be added by use of data acquired during different times of the year, to take advantage of details revealed by seasonal differences in vegetation or soil moisture. In general, however, a large percentage of the potential information on static phenomena can be obtained from a single, cloud-free pass over the area.

By elminating areas where further effort in mineral exploration is likely to be unrewarding, satellite data can identify the areas where more detailed study by aircraft and field work might be profitable. Several findings of minerals in various parts of the world have been facilitated by analysis of Landsat scenes.

On the basis of a rock-type classification map produced by digital computer processing of Landsat data, 30 prospect-target sites were chosen in a Pakistan area near known copper deposits. Out of the 19 sites visited, five yielded evidence of surface mineralization, indicating the possibility of an enriched zone of copper at depth.

A plan to make a new geological map of Egypt at a scale of 1:1,000,000 in 10 years at a cost of $2.4 million using black-and-white aerial photographs was altered when Landsat imagery proved to be more satisfactory. The latter offered roughly three times more geological detail and could accomplish the task more quickly at less cost. In three years, maps covering about half the country have been completed and the task is expected to be finished in two more years.

A second area of applications for Landsat data relates to dynamic phenomena. The particular value of space-based measurement lies in repetitive observation which makes possible the detection of short-period changes, such as those in a stream course following a major flood, or along a coastline after a major storm. Landsat images, for example, have enabled Bangladesh scientists to identify and measure the accretion of new land to islands in the Bay of Bengal.

MORE CANADIAN COMSATS

To keep pace with increased communications demands in the 1980's, Telesat Canada has announced the award of a $53.6 million contract to Hughes Aircraft Company of California to build three new communications satellites – the Anik C series. (Anik is an Eskimo word meaning brother).

When fully operational, the latest Anik spacecraft are expected to handle a significant portion of Canada's long-distance communications traffic within 1,000 miles of the U.S. border where most of Canada's 23,000,000 citizens live and work in cities and towns stretching through six time zones.

The first Anik C, scheduled for launch in early 1981 from the Space Shuttle, will be inserted into geo-stationary orbit over the equator between 105 and 120 degrees west longitude, almost directly south of Calgary, Alberta.

Anik C features 16 communications channels supplying audio, video and data telecommunications services, and will be one of the world's first satellites to provide telecommunications services in the superhigh frequency range (12-14 billion cycles per second).

The use of a technique called polarisation diversity on Anik C helps make possible a 100 per cent increase in communications capacity over the first Anik launched in 1972. The technique permits using the same frequency twice, doubling the effective capacity of the satellite.

Anik C will use an ingenious solar panel design which generates almost three times the power of the first Anik satellites. This expanded solar array consists of two concentric cylindrical panels which surround the body. When Anik C is inserted into orbit, its outer solar panel will extend downward, exposing both panels to the Sun and increasing power generation to over 900 watts. This design will also reduce launch costs by reducing cargo space required in the Shuttle.

Anik C is 12.6 metres (7 ft. 1 in.) in diameter and 6.43 metres (21 ft. 1 in.) high with solar panels and antenna deployed. The orbiting spacecraft will weigh 550.7 kg (1,214 lb.).

The new spacecraft will join three earlier Hughes-built Anik satellites, which became operational early in 1973 as the world's first national telecommunications service. Anik satellites are operated by Telesat Canada, a satellite communications firm owned jointly by the Canadian Government and 13 Canadian telecommunications carriers.

SATELLITE/IUS INTEGRATION

The Boeing Aerospace Company has received a $10,518,500 contract from the U.S. Air Force to integrate the Inertial Upper Stage (IUS) propulsion vehicle with satellites. The award from the U.S. Air Force Space and Missile Organization (SAMSO) provides $3 million in funding immediately. Boeing began work on the contract late last year under an initial funding of $1.1 million. The new award covers integration work for the next three years. Boeing also is IUS prime contractor.

Under the contract, Boeing will join satellites with the IUS boosters, check out the configuration and support launch and mission control operations for both NASA and the U.S. Air Force. IUS integration will be carried out both on Space Shuttle and Titan III launches.

The first IUS launch is scheduled for mid-1980 from the Space Shuttle Orbiter. Boeing will integrate the NASA Tracking and Data Relay Satellite with the IUS for this mission.

IUS is a space booster designed to take payloads to orbits unattainable by the Shuttle or the Titan III rocket.

NEW SOVIET TRACKING SHIPS

Two new tracking ships have been launched in the USSR, the *Kosmonavt Pavel Belyayev* built at the Zhdanov yard in Leningrad, and the *Kosmonavt Georgi Dobrovolski*. The *Belyayev* left Leningrad on 21 March together with the science ships *Borvichi* and *Nevel* to relieve the *Morzhovets* and *Kegostoy* which had maintained communications with Romanenko and Grechko on Salyut 6.

OTS 2 SPREADS ITS WINGS

After being delayed by adverse weather conditions and technical problems at Cape Canaveral, the European Space Agency's communications satellite, OTS 2, blasted off the pad at Cape Canaveral in the nose of the Delta 3914 launch vehicle on 11 May. The satellite replaced OTS 1 which was destroyed when its launcher exploded 54 seconds after lift-off on the night of 13-14 September last year.

OTS 2 (Orbital Test Satellite) is identical to its predecessor. Based on needs defined in consultation with European post office and broadcasting authorities, it has been designed for a minimum lifetime of three years in preparation for an operational European Communications Satellite (ECS) system. Development of the first two operational satellites was approved early in March this year and ECS-1 is scheduled for launch at the end of 1981. For this European regional system, the launch of a total of four operational satellites into geostationary orbit by Europe's Ariane launcher is envisaged between 1981 and 1990.

OTS 2 is intended to:

(1) demonstrate the performance and reliability in orbit of all on-board equipment;

(2) carry out experiments on the transmission of radio waves through the atmosphere, frequency re-use, etc;

(3) provide an adequate pre-operational European traffic capacity.

The satellite's capacity is equivalent to 6,000 telephone circuits. The coverage of its six SHF antennae will include not only the whole of Western Europe but also the Middle East, North Africa, the Azores, the Canary Islands, Madeira and Iceland.

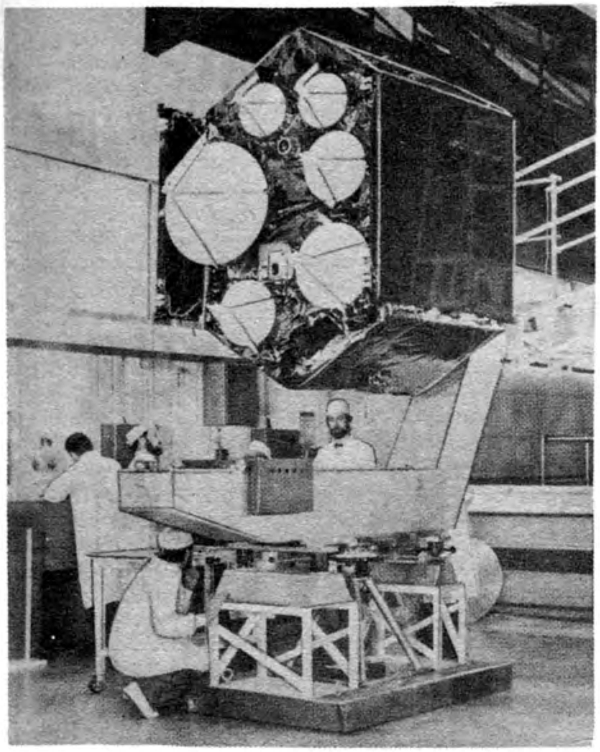
OTS 2 is one of the first communications satellites to operate in the 11 and 14 GHz frequency bands. The use of these frequencies is of particular advantage in Europe where the more usual 4 and 6 GHz satellite links would, in a regional service, be affected by radio interference.

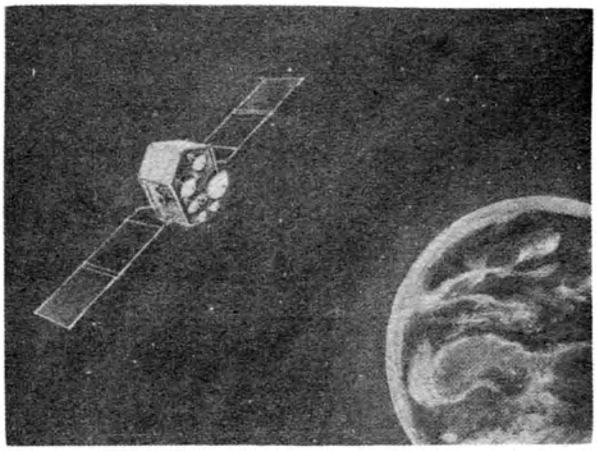
The six-sided satellite weighed 865 kg at lift-off (including apogee boost motor) and 444 kg in geostationary orbit. The spacecraft is 2.39 m high, 2.13 m long and measures 9.26 m with solar arrays deployed. The modularity of the OTS 2 design enables the satellite to be adapted easily and economically to other communications missions by a relatively simple change of payload. ESA's maritime satellite is the first such adaptation.

Built as a back-up satellite at the same time as OTS 1 and now converted into a second flight model, OTS 2 was

developed for ESA by members of the MESH consortium in 10 European countries (Belgium, Denmark, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom). The spacecraft prime contractor was Hawker Siddeley Dynamics (now British Aerospace Dynamics) and the payload prime contractor was AEG-Telefunken. Overall integration was the responsibility of MATRA. The OTS project was managed by ESA's Space Research and Technology Centre (ESTEC) at Noordwijk, Netherlands.

ESA and Interim Eutelsat, an organisation set up by the members of CEPT (European Conference of Postal and Telecommunications Administration), are jointly responsible for exploitating the satellite and for carrying out the experimentation programme in liaison with the national PTT Administrations and other users. ESTEC, in collaboration with ESA's Space Operations Centre (ESOC) at Darmstadt, Germany, and Telespazio, handle satellite exploitation activities from the main ground station for OTS tests, Fucino in Italy. ESOC is responsible for all satellite control and maintenance operations, including the delicate operation of injecting the satellite into geostationary orbit approximately

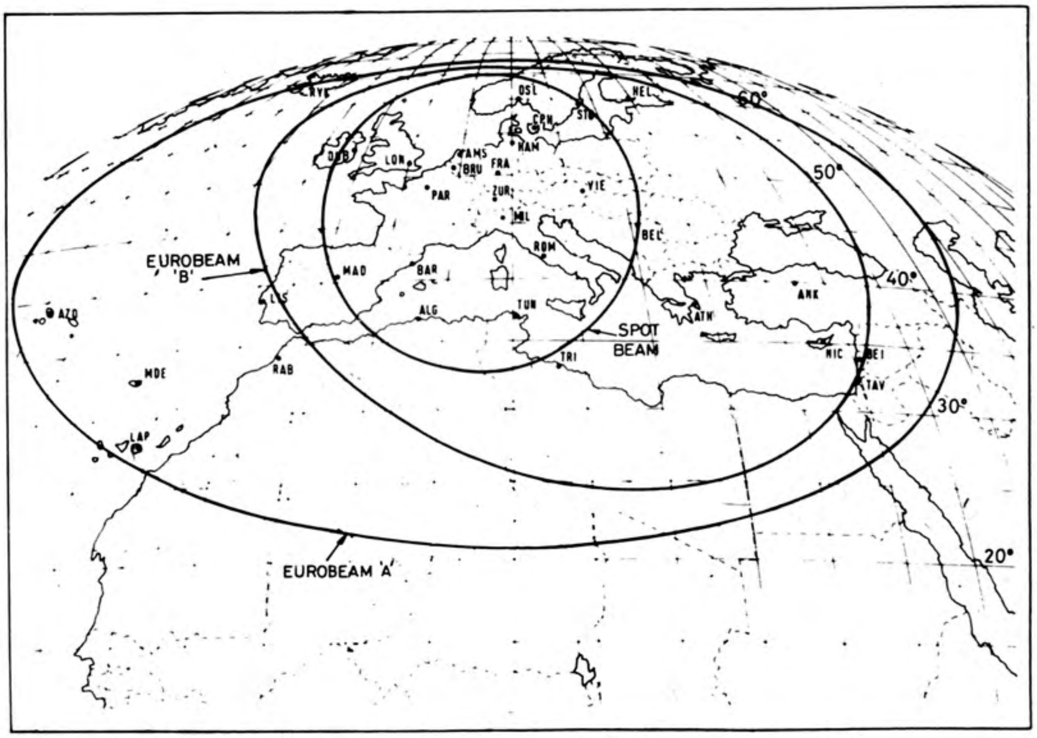




Above, technicians of British Aerospace Dynamics Group conduct moment of inertia test on Orbital Test Satellite (OTS 2).

Right, OTS 2 is the forerunner of ECS (European Communications Satellite), a fully operational European communications satellite system capable of handling a significant proportion of future European telephone, telex and TV traffic.

British Aerospace



OTS COVERAGE. From its position 35,880 km above the equator, coverage of the satellite's six antennae includes Western Europe, the Middle East, North Africa, the Azores, the Canary Isles, Madeira and Iceland. OTS 2 is one of the first communications satellites to operate in the 11 to 14 GHz frequency band. This is of particular advantage in Europe where the more usual 4 to 6 GHz satellite links are affected by interference.

ESA

40 hours after launch by the firing of an onboard apogee boost motor. After a series of drift manoeuvres, OTS 2 attained its on-station position at 10°E over Gabon some three weeks after launch.

In the coordinated communications test programme which begins this month, there will be two kinds of experiments: those requiring large Earth stations with antennae 15-19 m in diameter, of the kind envisaged for the future operational system, and those for which much simpler and cheaper terminals suffice. Four large European stations will have special OTS 2 antennae: Fucino (near Rome); Bercenay-en-Othe, near Troyes (constructed by the French PTT Administration); Goonhilly Downs in Cornwall and Usingen near Frankfurt (belonging respectively to the British Post Office and German Bundespost).

In addition, about 50 European institutes, universities and telecommunications authorities will participate in OTS experimentation using more than 30 small terminals, most of which have antennae of approximately 3 m although some go up to 14 m.

The follow-up operational system (called ECS for European Communications Satellites) will be designed to carry an important part of intra-European telephone traffic. It is planned that its capacity will increase progressively from an initial 5,000 telephone circuits in 1981 to 20,000 in 1990.

SALYUT 6 PRESS CONFERENCE

On 11 April 1978, the cosmonauts who participated in the first international space mission aboard the Salyut 6 orbital laboratory gave their first press conference since returning from orbit, writes Neville Kidger.

The conference was opened by V. N. Sofinskiy, head of the press department of the USSR Foreign Ministry. Sofinskiy congratulated the cosmonauts on the mission and the awards that the Soviet Union and Czechoslovakia had bestowed on them. Academician Boris Petrov, Chairman of the Interkosmos Council of the USSR Academy of Sciences said, during his address, that "Soviet science regards the creation of orbital stations with replaceable crews as man's main road to outer space." The successful accomplishment of a complex space flight involving four dockings of transport ships with the Salyut 6 station in as few as three months was made possible by the dedicated work of thousands of people who had built the sophisticated space equipment and ensured the launching of the station and spaceships and control of their flight, and by the heroic work of the cosmonauts that crowned the work of many labour collectives. Yuri Romanenko and Georgi Grechko accomplished a vast amount of scientific work both independently and together with the visiting crews – Vladimir Dzhanibekov and Oleg Makarov, Alexei Gubarev and Vladimir Remek. These crews made up, according to Petrov, one scientific collective of space researchers, close-knit personnel of an orbital laboratory.

From the medical point of view the most important results of the flight of the basic crew of Salyut 6, Romanenko and Grechko, was that they retained sufficient capacity for work and successfully carried out their mission, Dr. Oleg Gazenko told the conference. All experiments and observations "were carried out by the crew with unflagging interest and even with inspiration until the last day of the flight."

In his account of the medical aspects of the flight, Gazenko said that during the first days of the mission the blood rushed to the cosmonauts heads and they experienced an unpleasant feeling mainly because of the increased flow of blood to the upper parts of their bodies and the reduction of co-ordination in their sensory organs under conditions of zero g. After the first month, he said, cardiac activity had become more regular, showing that some new balance had been established by the cosmonauts hearts. During the flight doctors on the ground had given advice on how to avoid the adverse effects of weightlessness.

During the flight's last two months or so the cosmonauts had spent 10-12 hours per day in the 'CHIBIS' "walk-around" lower body negative pressure suits that created extra work for the cardiovascular systems by pooling blood into the lower extremities. In addition the crew spent 1-3 hours per day exercising. Gazenko said that on their return to Earth they had worn suits "to exert pressure on the lower extremities to prevent an accumulation of blood in them when they were in an upright position on Earth." During the flight the cosmonauts had felt "an increase in the weight of their own bodies." However, on their return to Earth they "had to make a noticeable effort to keep erect" and "felt much better when lying down." Their movements had at first not been smooth.

Though "the body weight of each cosmonaut immediately after landing had dropped by about five kilogrammes" it had been noted that "as early as the second day after landing and after the restoration, to a considerable extent, of the liquid their bodies had lost" the weight loss had been only 1.5-2.5 kg, and that there had been "a noticeable reduction in the size of the lower extremities. It was found that the two men had lost 1.5-2 cm from the circumference of their legs due to inactivity of the leg muscles in zero g, and they had returned to Earth with reduced heart volumes. According to *Aviation Week and Space Technology* the leg and heart data are similar to those gathered by the Skylab astronauts, although the Skylab astronauts did not have any 'walk-around' suits. On returning to Earth the crew had felt heavier and had found that standing erect was something of a strain for the first few days. Grechko, who had experienced chest pains after returning from his 30 day Salyut 4 flight in 1975 experienced no such problems after his return from Salyut 6. He had found readaptation to 1 g easier than before. The post-flight examinations which had broadened scope through the inclusion of a number of new methods – supersonic sounding of the heart and a large spectrum of biological and haemotological studies – detected no changes differing radically from those known before. On the whole, Gazenko said, the vast amount of scientific data obtained "is of great significance both for a better understanding of man's reactions to outer space and for a further perfection of the methods of medical control."

Romanenko said that in preparation for carrying out the longest ever manned flight "we took account of the experience of all the long-duration flights carried out before by the Soviet and American cosmonauts."

Romanenko said that the most memorable event of the flight from his point of view was the work aboard Salyut by the international crew, Gubarev and Remek. He said that the whole of their work on Salyut would have been impossible without the vast amount of work put in by a large number of scientists, engineers and workers, who created such a reliable vehicle and without the efficient and well-co-ordinated work of the Gagarin Centre for Cosmonaut Training, which prepared them for the flight. He also expressed his gratitude to the workers at the Cosmodrome, the flight control centre and the command, measurement and search-and-rescue complexes supporting the flight. He also revealed that although he was told to remain in the transfer compartment during the space walk on 20 December, he wanted to see the world outside and made an unauthorised exit from Salyut (probably no more than sticking his head out of the docking unit hatch).

Grechko devoted his address to the scientific instruments and experiments conducted during the flight, particularly the Geophysical and Earth observation and atmospheric studies related to geology, geography, oceanology, agricul-

ture and forestry. Processing of the photographs taken in orbit is being completed,Grechko said. Pictures taken during the first month of the flight were returned to the Earth by the Soyuz 27 cosmonauts in January and later some of the results of their photography were brought back to Salyut by the Soyuz 28 crew to help the crew determine where additional photography was needed. Grechko said that some of the materials processing experiments had been hampered by small gravity loads on the materials being processed, even though the Salyut was put into a drifting mode during the experiments to dampen such forces caused by the use of spacecraft thrusters for attitude changes. It is thought that these perturbations came from cosmonaut movement within the station during the experiment. Some very interesting results had been obtained concerning polar lights. These, Grechko speculated, are linked somehow with luminous clouds.

Czechoslovakian cosmonaut researcher Vladimir Remek said that he was honoured to have been a member of the first international space crew; "I should like to thank all the specialists who helped me prepare for the flight, study many theoretical disciplines and sophisticated space equipment. I am glad to have met Alexei Gubarev who shared his rich experience with me. The launch, the first sensation of weightlessness, the first glance at my dear Czechoslovakia from orbit, the docking with Salyut 6 and the meeting with friends – all this merged into one beautiful moment," Remek told the assembled newsmen. He said that his first steps on the Earth after landing were a unique sensation, incomparable with anything."The feet feel heavy, you step along cautiously and the Earth seems dearer to you than it was before the flight."

Academician Petrov told the newsmen that the next manned space flights, planned for 1978, would include cosmonauts from Poland and the GDR who were currently in training in the USSR. The flights would be 8 or 9 days long. Another 'Progress' flight to supply the station was also planned. Missions involving longer stays in space than that of Romanenko and Grechko would not be decided until after a complete and careful study of their 86 day flight.

Before the press conference, the members of the expedition were decorated with the Soviet Union's highest awards by President Leonid Brezhnev. In making the awards he said, in a long speech, that Soviet science saw the development of orbital stations with replaceable crews as the main road to outer space.

At another awards ceremony the USSR Academy of Sciences presented Tsiolkovsky Gold Medals to Gubarev, Grechko and Pyotr Klimuk. The medals honoured their work on the Salyut 4 station in 1975. Vitali Sevastyanov, who also worked aboard Salyut 4 already has a Tsiolkovsky Gold Medal for his work on the 1970 Soyuz 9 long-duration flight.

SOVIET SPACE FUTURE

Soviet scientists have been discussing some planned developments of the Salyut space station and the need for orbital power stations similar to those being discussed in the United States, writes Neville Kidger.

When asked to comment on the future development of space stations Yuri Zaytsev, head of the Space Research Institute, said: "Opinions differ on the line of development, though prominent Soviet scientist-cosmonaut Konstantin Feoktistov believes that even today so many instruments are installed aboard orbital stations that the crews often have too much on their hands. So it would be impractical to build much bigger stations than Salyut, at least at present."

On being asked how many cosmonauts modern space stations would accommodate and for how long, Zaytsev answered that they were meant for two to four people. "Control of the on-board instruments is largely automatic and that enables the space crew to carry out complex experiments. The station can function for months on end, and even years, both when manned and in automatic duty. However in future it may become more practicable to build stations which will work for decades with some 20-30 cosmonauts working in shifts. And as a long-term objective I could mention super large multi-purpose space complexes meant for 100 and more spacemen." With the help of space laboratories, studies would be made of the planet's mineral resources and of terrestrial and interstellar space. Orbital stations also would serve as a link between the Earth and other planets, helping to solve the numerous problems of preparing for interplanetary flights.

Academician Sagdeyev said that initially the production complexes established in space would be of a type which could not be set up on Earth at all, and that in the next 10 years metallurgical, engineering and chemical facilities would be organised on-board space stations in Earth orbit.

In the magazine *Ogonek,* Konstantin Feoktistov said: "Calculations show that it is possible to solve the problem of providing power for the Earth with the aid of orbital power stations." A space power station, in his opinion, will convert the Sun's energy into electricity and then relay this energy to Earth in the form of microwaves. "Technically we could perform this task today. The working element of such a station is a special film stretched over an open-work frame (the solar battery), which is not destroyed by the effects of ultra-violet rays. The area of such stations will be enormous, several tens of square kilometres," he said.

Feoktistov considers that construction of stations will begin in space within two or three decades. "I think that by that time orbiting power stations will be quite capable of competing with those on Earth. Experiments will begin before that, of course. In essence they have already begun."

Going further afield Feoktistov said of exploration of the planets: "It is extremely tempting to look for life on other planets of the Solar System, and try to establish the genetic code of life. If 'they' and 'we' have different codes, then there are grounds for supposing that the spontaneous generation of life should be spread throughout the Universe, and that we are not alone. But if the code proves to be the same as ours, this will be perplexing."

The above comments were published in connection with the celebration of Cosmonautics Day in the USSR on 12 April, the day on which Yuri Gagarin, in 1961, became the first man to travel into orbit.

ROBOT SPACE ARM

A robot-like device which could remove faulty modules from an orbiting spacecraft, replace them with new ones and return the malfunctioning modules to Earth for repair or expend them in space is under study at NASA's Marshall Space Flight Center in Huntsville, Alabama. An Orbital Servicing Study performed under Marshall Center direction by the Martin-Marietta Corporation has indicated that savings of up to 30 per cent may be obtained by this method in the Space Shuttle era.

A series of spacecraft servicing preliminary design and simulation activities by the contractor firm has led to the design and fabrication of an engineering test unit capable of demonstrating space maintenance operations. The unit, known as an Orbital Servicing System, was delivered recently to the Marshall Center's Electronics and Control Laboratory.

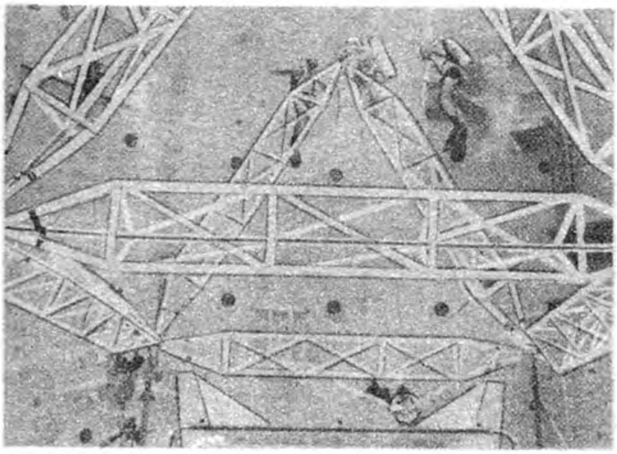
The Orbital Servicing System – deployed in Earth orbit by the Shuttle, and transported to advanced orbits aboard a space tug – would be remotely controlled to rendezvous

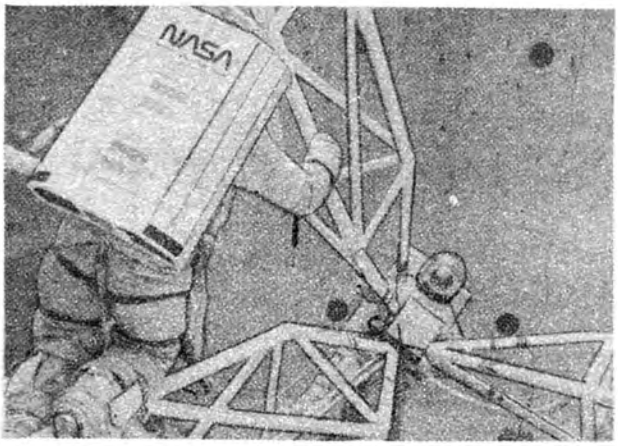
and dock with a disabled spacecraft. Servicing would then be performed by the robotic arm to replace faulty modules with new ones carried aboard the platform-like servicing system.

Marshall Center engineers are currently evaluating three alternative control methods: (1) computer automated; (2) computer manually augmented, or (3) purely manual. It is anticipated that the flight version would use the computer automated mode with manual backup in reserve.

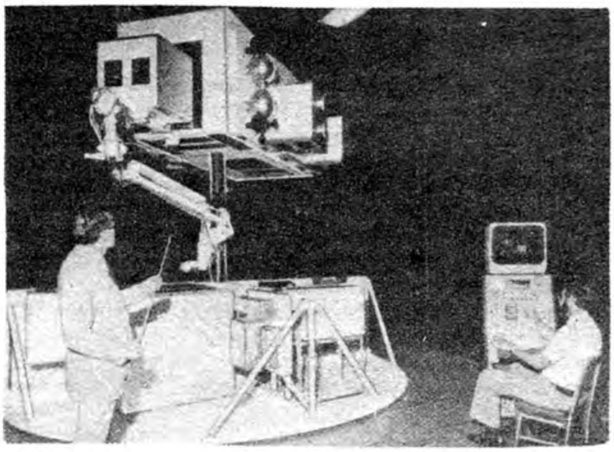
The operator for the servicing system could be on the ground or aboard the Space Shuttle. A television camera, with floodlights, mounted on the system's robotic arm would provide the operator with a closeup view of the servicing system as it performed its maintenance function in space.

The engineering test unit at Marshall includes mechanisms, controls and spacecraft mockup necessary to demonstrate module removal and replacement which would be required in future orbit-maintainable spacecraft. A computer and computer programme are being provided by Marshall Center labs.





SPACE ASSEMBLY. Two engineers wearing spacesuits perform one of a series of tests in space structure assembly in the simulated weightlessness of the Neutral Buoyancy Simulator at NASA's Marshall Space Flight Center. The test dealt with assembly techniques and determining problems to be encountered in handling and moving large beams during assembly of a large structure in space. The space-suited engineers, Leon Weaver and Steve Hall, are accompanied in the simulator by diving technicians for safety and assistance. In later tests space-suited astronauts are expected to participate. Witnessing the test were about 30 people from the U.S. Department of Defense and 25 from other NASA centres and headquarters who were attending a Large Space Structures Conference at Marshall Center.



ROBOTIC ARM. Servicing of satellites in orbit might be performed by a robot-like device like this one being tested at the Marshall Space Flight Center at Huntsville, Alabama. The robotic arm is shown removing a box representing a faulty module in a spacecraft. The arm will then store the malfunctioning module on the servicing platform and replace it with a new one carried aboard the platform. John Burch (left), MSFC test supervisor for the device, watches the operation, as Don Scott operates a control panel that commands the arm's actions.

All photos National Aeronautics and Space Administration

THIRD WORLD SYMPHONIE

After three years in space, the Symphonie 1 and 2 satellites can boast an excellent record. The two spacecraft are fully occupied with international commitments, and it is to be expected that they will both continue to be operational beyond their planned lives of five years.

The outstanding results obtained from Symphonie have considerably expanded the technical capability of the German and French industry involved in the programme and also helped forward bilateral cooperation. The most impressive result of this cooperation and the technological experience that it has brought with it is the inclusion of the three Symphonie companies. Aérospatiale, MBB and Thomson-CSF, in the Intelsat 5 programme led by the United States' Ford Aerospace company. This is the first time that civil communications satellites in the Intelsat series will be stabilised in three axes, rather than spin-stabilised. This technology, developed for Symphonie, is one of the most important European contributions to the world-wide communications satellite programme.

Symphonie is being used today both at home and abroad for conferences, exhibitions, meetings, cultural exchanges and in disaster situations. A network of 37 ground stations now covers the Earth; 17 of them are in permanent operation, ten from time to time, and another ten are reserved for technical demonstrations.

Symphonie has meanwhile become firmly established in the countries of the Third World as an example of European space technology. India, Egypt, Iran, Ruanda, the Ivory Coast, Gabun and Libya all use Symphonie for technical and cultural experiments, for example under their educational television programmes. Indonesia is making technical experiments with the satellite. The Soviet Union has asked for transmission time to broadcast the 1980 OlympicGames. The People's Republic of China would like to use the 'Indian' Symphonie satellite for telecommunications purposes. Mozambique has applied for Symphonie capacity, and Thailand is having technicians trained on Symphonie ground stations at Ottobrunn.

NASA SEEKS SPACE VENTURERS

New and improved products in medicine, metals and other materials may become available to the public within a few years as industrial companies move into commercial ventures in materials processing in space, writes Christine Duncan of the George C. Marshall Space Flight Center, Huntsville, Alabama.

NASA is actively seeking private firms to engage in Materials Processing in Space so that beneficial space processes and space products can be put within reach of the public as early as practical. A special task force has been established at NASA's Marshall Space Flight Center, Huntsville, Alabama, devoted exclusively to working with firms interested in pursuing space-made or space derived processes and products.

The team, headed by Richard L. Brown, provides a single point of contact for information and assistance to firms with ideas for new or improved products that might be processed in space. "We intend to develop simplified working arrangements, "Brown said, "and make it as easy as possible for commercial firms to try out new ideas for materials processing in the space environment."

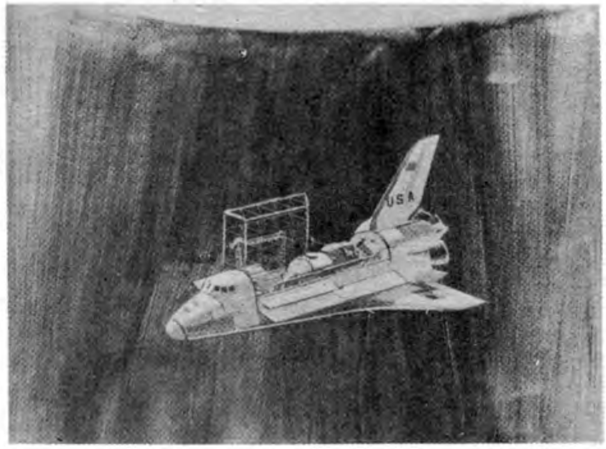
Brown pointed out that previous space experiments have shown promising results, and that these experiments, coupled with the upcoming capability to work routinely in space on the Space Shuttle, opens the door for commercially attractive materials processing ventures.

"When gravity is reduced to one-millionth of that on Earth," Brown said, "a lot of interesting things happen. For example, the forces of buoyancy, sedimentation and movement in fluids caused by heat are virtually eliminated. This opens the door to uniform mixing of materials that cannot be mixed on Earth, and separation of materials that cannot be separated on Earth. This suggests that there are families of new materials that can come from materials processed in space."

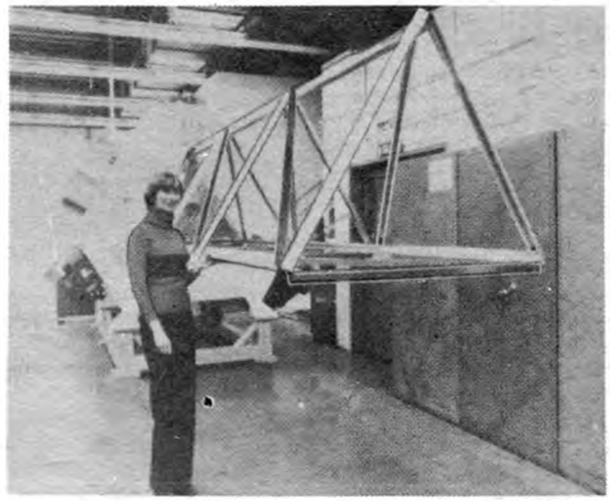
A limited number of opportunities to fly experiments will be available to commercial firms by 1980. Opportunities are expected to be routinely available within five years. Three avenues to commercial ventures are open to interested firms: joint endeavours in which the total cost of the experiment or demonstration is jointly shared by NASA and the company, but in which there is no exchange of funds; industry-funded ventures where industry pays for development of the experiment package and a *pro-rata* share of integration, operation and flight costs; and government-funded ventures resulting from NASA solicitations for proposals from industry through formal competitive announcements.

To reduce initial capital outlays needed by industry for joint endeavours and industry-funded ventures, NASA is planning to build an inventory of general purpose processing hardware which can be leased if companies so desire. Brown said that any U.S. firm, institution or individual may participate in the programme and conduct materials experiments or demonstrations that are consistent with NASA's objective of fostering public benefits. "And," he added, "waiver of invention rights by NASA will be considered in joint ventures, when it is determined to be in the public interest."

A brochure just published by the task team outlines why microgravity and high vacuum make the space environment unique for processing materials that may one day benefit the public. It also lists some materials and applications that show promise and explains what NASA is doing to facilitate the commercial use of space for materials processing. Brown stated that anyone who is interested in the programme may contact the task force on application to the Commercial Space Processing Development Office, Mail Code PF12, Marshall Space Flight Center, Alabama 35812.



BEAM BUILDERS. This artists's concept depicts the use of the Space Shuttle Orbiter to carry an advanced technology laboratory into Earth orbit to support construction in space. The lab has a pressurized model in which engineers work in a shirtsleeves environment, and an airlock from which they can emerge in spacesuits to assist the assembly of large structures.



An automatic device for forming continuous structural beams in space is nearing completion at Grumman Aerospace Corporation, Bethpage, New York. The automated 'beam builder' is being developed for MSFC to demonstrate techniques for fabricating large space structures. The device forms triangular beams from flat rolls of very lightweight materials. The machine could form continuous beams kilometres in length for building such large structures as may be required for satellite solar power stations.

National Aeronautics and Space Administration

THE SKEAN PROGRAMME

By Phillip S. Clark

Introduction

On 18 August 1964 the Soviet Union launched Cosmos 38-40 into an eccentric orbit, and stated that the payloads "were put into orbit by a single carrier rocket of a new type" [1]. The launch had been used to confirm the high quality of the new carrier rocket's characteristics, and the payloads were carrying out the usual scientific missions announced for Cosmos satellites.

Observers of the Soviet space programme felt that the launch vehicle was based on the SS-5/Skean missile, which belongs to the same family as the SS-4/Sandal which forms the basis of the smaller Cosmos rocket or B-1 vehicle.* The Skean's orbital capacity was estimated to be generally between those of the Sandal vehicle (about 600 kg) and the Vostok rocket (4750 kg), but closer to the former. The Soviets have given no indication of the masses for the Soviet-built payloads.

The Skean is the only one of the five operational satellite launch vehicles to have seen service at all three of the Soviet launch sites. The initial development flights came from the Tyuratam launch complex, and in 1967 operational missions appeared from Plesetsk: the first Kapustin Yar launch was not until 1973. By the end of 1977 the Skean launch vehicle had become the third most-used launch vehicle in the world, surpassed only by the Soviet SS-6/Sapwood (A-class vehicle) and the American Thor in that order. A summary of the annual launch totals in given in Table 1.

The Launch Vehicle

The Skean missile belongs to the same family of Soviet missiles as those which had their origins steeped in the V2 technology, and it can probably be regarded as the ultimate post-war development of the basic concept of that wartime German missile [2]. The SS-5 weapon is now reportedly being replaced by the newer SS-20 missile [3], and presumably this has released more weapons for use as satellite launch vehicles in recent years.

The final identification of the Skean with the first stage of the C-1 intermediate launch vehicle came in 1974-5 when the first pictures of the complete launch vehicle were released; the first showed the lift-off of Intercosmos 10 [4], although the picture is not too clear. Some clearer pictures have now been released showing Intercosmos 12 and 16, Ariabat and Signe-3,† and these have enabled the size of the vehicle to be scaled. Various estimates of the SS-5 diameter have been made, but taking 2.44 m gives a length of 31.2 m ± 0.6 m. The Skean launch vehicle has two stages, and values for these are given in Table 2. A cross-check of the first stage length was made, scaling with a picture of the SS-5 missile on display, and this gave a length without the warhead only about 0.2 m different from that in Table 2. The second stage has a capacity for multiple burns, and this is used in the launch techniques on high altitude flights. The first stage and second stage place the combined second stage and payload on an ascent ellipse, and at apogee the second stage re-ignites for the final orbital injection.

Some details for the first stage engine have been released, with the figures quoted by Vick [5] being given in Table 2. Subsequently, some slightly different values (thrust 175 tonnes, specific impulse 284 sec.) were quoted by Pauw [6]. Two RD-216 engines power the first stage, which is apparently fuelled by UDMH and nitric acid. The values in Table 2 for the second stage engine are estimated: a similar specific impulse (Isp) as for the RD-119 engine (the second stage on the Sandal launch vehicle) is given, while the thrust is estimated from the general mission requirements.

Payload Capacity

Although no masses have been released for any of the Soviet payloads, masses have been announced for two non-Soviet flights:-

Ariabat	(Indian)	360 kg
Signe-3	(French)	102 kg

Estimates, based on the data in Table 2, of the *theoretical* payload masses of the Skean to the various types of circular and eccentric orbits which have been used are given in Tables 3 and 5. It is hoped that these values are of the correct order, perhaps to within 10% or so. The announced payload masses fall far short of these estimates, and it can only be assumed that the Soviet home-grown payloads tax the launch vehicle to a greater extent. However, it is not suggested that the vehicle's full capacity is used for each of the orbital slots shown in Tables 3 and 5. For example, the navigation flights at 990 km and inclinations of 74° and 83° use basically the same satellite, and it would be dangerous to conclude that the satellite masses were cut by about 40 kg when the system was up-rated.

Satellite Missions

In common with the overall Soviet programme, the majority of the Skean payloads are military in nature, and one can only make inspired guesses at their actual missions. However, starting in 1970, payloads appeared which were scientific in nature, and over the next few years the Skean took over more and more flights which would previously have used the smaller Sandal vehicle. Starting with Intercosmos 10, all the Intercosmos launches have used the Skean. While the early Skean Intercosmos missions used basically the same type of spacecraft "bus" as used on the Sandal flights, a new up-rated "bus" – the AUOS (automatic unified orbiting station, [7]) – is now in use. It seems possible that Intercosmos 15 was the first test flight of the AUOS unit, while Intercosmos 17 was the first operational flight.

In the following sections the satellites are divided into circular and eccentric orbit missions. The former are then broken down into sub-sets with the possible missions indicated and any interesting orbital spacings noted. Since they form a smaller set, all the eccentric orbit flights are grouped only by launch site.

For details of the lines of research undertaken on the scientific flights the reader is referred to *Soviet Space Programs, 1971-75* [8] and, for the more recent flights, to the "Milestones" notes in *Spaceflight*. Unless otherwise indicated, the identification of the possible military satellite missions follows the analysis of Sheldon [9].

Circular Orbit Flights

(a) Kapustin Yar

The small Kapustin Yar launch site has never been

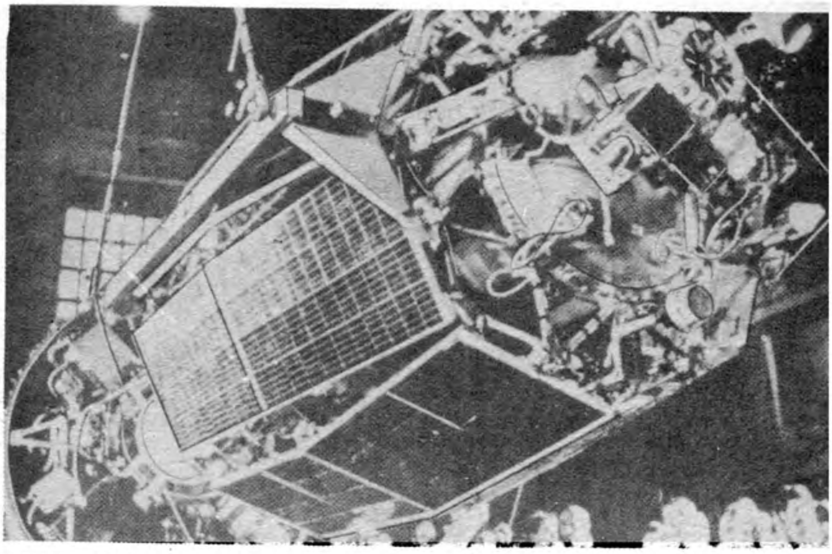
* *Nomenclature due to C. S. Sheldon II, "The Soviet Space Program, A Growing Enterprise," TRW 'Space Log,'* 8, *8-19, Winter 1968-69.*

† *For example, see the following: Intercosmos 12, 'Spaceview,' Jan/Feb 1975, 35/35; Ariabat, 'Informatie Bulletin,' 10 July 1975, 9; Intercosmos 16, 'Aviation Week & Space Technology,' 30 August 1976, 42; Signe-3, 'Aviation Week & Space Technology,' 18 July 1977, 57.*

Intercosmos 17 satellite in assembly, the first operational use of the AUOS. The satellite was launched on 24 September 1977.

Below, French Signe 3 satellite in assembly after being attached to the second stage of the launch vehicle.

Novosti Press Agency



807 flew in similar orbits to Cosmos 426 and Oreol-2, but have had no scientific missions announced.

Remaining Skean Space Missions

The Skean has been adapted for sub-orbital space missions, as well as for orbital use. The Vertikal series of flights initially used the Sandal single-stage vehicle, but photographs show that Vertikal-4 (October 1976) was based on the Skean without its second stage. Possibly Vertikals -5 and -6 (in 1977) were also based on the Skean.

The public record does not show any launch failures involving the Skean, but the Intercosmos failure of June 1975 might have used this vehicle. The launch came from Kapustin Yar, and should have put the payload – which in-

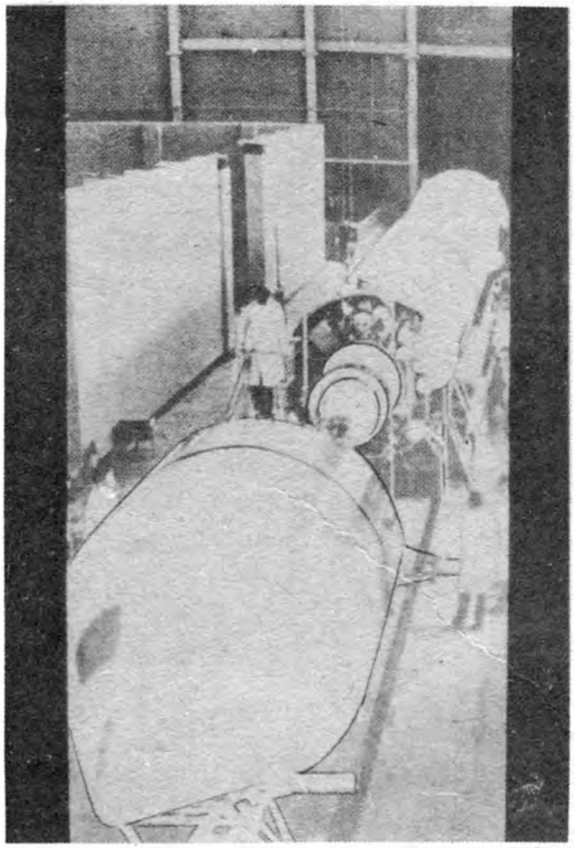


Table 4. List of Skean Payloads (Circular Orbits).

Site	Incl °	Alt km	Period min	Flights
KY	50.6	495	94.5	*11**, *16**, 906, Signe-3*
		590	96.5	546*, Ariabat*
TT	56.0	530	95.2	71-75
		615	97.0	103, 151, 236
		1450	114.9	80-84, 86-90
PL	65.8	240	89.3	459**
		395	92.5	933
		495	94.5	752, 816, 885, 891
		590	96.5	394**, 803**, 880**
		990	104.9	400**, 521, 967**
	69.2	495	94.5	461*
		1385	113.4	708
	74.0	495	94.5	*15**, 913, 930, 965
		530	95.2	189, 200, 250, 269, 315, 330, 358, 387, 395, 425, 436, 437, 460, 479, 500, 536, 544, 549, 582, 610, 631, 655, 661, 698, 707, 749, 781, 787, 790, 812, 845, 870, 899, 924, 960
		755	99.9	158, 192, 220, 292, 304, 332, 371
		800	100.9	372, 407, 468, 494, 540, 614, 676, 773 783, 836, 841, 858, 923, 968
		990	104.9	381*, 385, 422, 465, 475, 489
		1190	109.2	203, 256, 272, 312, 409, 457
		1385	113.4	539, 585, 650, 675
		1450	114.9	335-343, 411-418, 444-451, 504-511, 528-535, 564-571, 588-595, 617-624, 641-648, 677-684, 711-718, 732-739, 761-768, 791-798, 825-832, 871-878, 939-946.
	83.0	495	94.5	900*, *17**
		990	104.9	514, 575, 586, 627, 628, 663, 689, 700, 726, 729, 755, 778, 789, 800, 823, 842, 846, 864, 883, 887, 890, 894, 911, 926, 928, 951, 962, 971
		1190	109.2	480, 770, 963

Notes. (1) The flights are grouped by launch site, orbital inclination, mean orbital altitude and orbital period.
(2) Joint Soviet-Bloc *Intercosmos* flights are shown in italics. Other numbers are Cosmos missions. Other programme names are shown when required.
(3) Scientific missions are followed by *.
(4) Targets for hunter-killer satellite missions are followed by **.
(5) Signe-3 is French and Ariabat (Aryabhata) is Indian.

Table 5. Summary of Skean Payloads (Eccentric Orbits).

Site	Incl °	Orbit km	Period min	Mass kg	Flights
TT	56.0	205-770	94.4	1305	38-40
		260-1735	105.1	1000	54-56, 61-63
PL	65.8	145-850	94.6	1965	959**
		990-2100	117.0	565	839**, 909**
	74.0	245-710	94.1	1180	*12**
		285-705	94.5	1195	687, 822
		260-1455	102.1	940	*10**
		235-1740	104.8	890	378*
		335-1680	105.3	875	*14**, 893
		395-1985	109.2	775	426*, Oreol-2*
		400-2480	114.7	665	Oreol-1*
	83.0	285-1700	105.0	845	*13**
		400-1970	109.1	735	660,807

(Notation in this Table follows Tables 1 and 4).

Notes. (1) Mean perigee and apogee are used to define the orbit, rather than mean altitude.
(2) The two Oreol (Aureole) satellites carried French experiments.
(3) This Table combines the functions of Tables 3 and 4 for circular orbit missions.

cluded Swedish experiments – into a 49°, 280-600 km, 93.4 minute orbit [18]. The orbital inclination is not a perfect fit for either the later Sandal (48.4°) or the Skean (50.6°) launch vehicle. The last Sandal flight from Kapustin Yar was in April 1973 (Intercosmos 9, also called Copernicus-500), so the Skean would seem to be the logical vehicle for the mission. The replacement flight – Intercosmos 16 – certainly used the Skean.

In addition to the orbital launches already described, there have been three other Cosmos flights in 1977 from Plesetsk, and they all used a new inclination of 75.8°. The orbital data is as follows:

Cosmos 921	620 - 700 km	98.0 min
Cosmos 956	355 - 865 km	96.9 min
Cosmos 972	715 - 1170 km	103.9 min

Apart from the inclination Cosmos 921 is similar to known Skean-launched missions: the other two, however, are not in Skean-type orbits. Skean flights come regularly at 74°, so one must ask: "What can be done at 75.8° that cannot be done at 74° when the same rocket is used?" These three flights might have used the Skean, but this is not yet certain. One possibility is that they represent the first space use of one of the newer-generation Soviet missiles, perhaps the SS-11.

Summary

The Skean programme has greatly expanded in the 1970's, and has now all but taken over from the older Sandal launch vehicle. At the time of writing, the launch rate seems to be about 30 per year, and presumably this will continue for the rest of this decade. If the SS-11 missile is being introduced for satellite launches, we might see the Skean being phased out in the early 1980's, just as the Sandal has now virtually disappeared.

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AMERICA'S SEA VIEW SATELLITE

A satellite with a sea view which could help to provide better weather forecasts and reports and so save shipping companies millions of pounds a year, was being prepared for launch at Vandenberg Air Force Base, California, as we closed for press. Called Seasat A (Seasat 1 in orbit), it has cost £20 million ($36.5 million) and is the first U.S. satellite to have been specially designed to monitor ocean conditions. The experiment is meant to discover how data from a network of such satellites could improve the efficiency of the shipping and offshore industries. A study of the potential benefits carried out for the National Aeronautics and Space Administration, which has sponsored the Seasat tests, predicts that up to £1,100 million ($2,000 million) could be saved in the USA alone by the year 2000.

Seasat circles the Earth 14 times a day covering 95 per cent of the sea every 36 hours relaying information on surface winds, temperatures, currents, wave heights, ice conditions, ocean topography and storms. This information can be used to improve weather forecasts, route ships to avoid bad weather, save fishing fleets time and fuel by indicating where particular species are shoaling, and detect small icebergs and navigable openings in icefields. It should also help oil exploration companies to select the best site for offshore rigs and provide warning of storms which might threaten platforms and disrupt operations.

Built by Lockheed Missiles & Space Company, Seasat gathers data through five microwave sensors rather than by using photography. These sensors measure the roughness of the sea which can be converted into wind speed and direction within an accuracy of two metres per second, measure the temperature within one degree C and report wave heights to within 0.5-1.0 metres – all from a height of some 800 km (430 nautical miles). The satellite is 12.2 metres (40 ft.) long and weighs 2,274 kg (5,000 lb).

COSMONAUT TRAINING

By Major-General Alexei Leonov*

Introduction

Cosmonautics is developing at a rapid pace, uniting, concentrating and embodying many of the latest achievements of science and technology. Manned spacecraft such as the transport vehicle Soyuz or the Salyut space station are reliable and well designed but they are immeasurably more complex than any other transport vehicle ever devised by mankind. And space has not become more hospitable: high vacuum, weightlessness (which proved more formidable than we knew), penetrating radiation, meteoroids and many other unpleasant surprises await man outside his native planet. It is far from simple to train a person to control a spacecraft, to cope with all kinds of surprises, to live and work in zero-gravity conditions, and to carry out a packed and varied scientific programme.

I am convinced that it will always be difficult for everyone, even the most highly trained, to prepare for a space flight. Work in space has been and will remain complicated.

Training Procedures

Even compared with the early 70's when Valery Kubasov and I trained for the first international Soviet-US manned flight within the ASTP programme a great deal has changed in the training process. Priority is now given to tasks connected with prolonged stay of crews in orbit. Important new features have been developed and used in the present Salyut 6 mission such as the two docking units, and the unmanned ferry craft Progress 1. We have come close to solving a cardinal problem of contemporary cosmonautics: the search for the optimum length of human stay in weightlessness and in an artificial habitat.

Vladimir Remek and his colleagues – pilots from the German Democratic Republic and Poland – began their studies at the training centre early in December 1976. The first stage included theoretical studies combined with flight experience in jet planes, physical exercises, simulation of zero-g flights, practicing elementary procedures of splashdown, retrieval by helicopters from thick forests, mountains and other difficult terrain. Our future cosmonauts have to go through severe trials in order to learn, using the small emergency ration of water, clothes and food available aboard the ship, to spend a few days in winter tundra or waterless desert after landing off target.

Our new student cosmonauts studied theory, absorbing the fundamental dynamics of space flight, mathematics and ballistic calculations, the fundamental design of space vehicles, astronomy and astro-navigation, and computers.

The working day exceeds 12 hours. All members of the group live and work according to the schedule, as otherwise it would be impossible to keep up with advances in space technology. A few hours of studies at home and preparation for the next working day is usual too. Add to this the obligatory clinical and physiological check-ups (every three months) and you will understand the requirements set by medical specialists for the absolute good health of trainee cosmonauts.

The experience of space flights has shown that in a gravity free world man needs stamina rather than strength, as well as balanced psychological reactions, instantaneous reactions to a changing situation and considerable reserves of the cardiac and vascular system. So sports are an important part of the general training of cosmonauts.

The initial period of training for Vladimir Remek and his colleagues ended with examination in more than a dozen special scientific subjects which all successfully passed.

Cosmonauts of first international space flight Soyuz 28 in training for emergency sea recovery: Col. Alexei Gabarev (right) and Czech cosmonaut Capt. Vladimir Remek.

Novosti Press Agency

The second stage began last August. This consisted in mastering the Soyuz craft and the specific programme for a visit to the space station Salyut. During this period the training was conducted at crew strength. The future Researcher Cosmonauts were acquainted with their Commanders, all of them experienced Soviet Pilot Cosmonauts who had already been in space. Now the crews were training according to individual schedules promoting the development and assimilation of solid professional routines. This is far more complicated than absorbing a theoretical concept of the flight.

With cosmonauts from other countries taking part we have to take into account their personal inclinations, habits and tastes. A long stay away from one's country, away from one's friends and relatives, and intensive work in a new situation – all that is not so simple. We try to make the everyday problems of our friends from the socialist countries and their families as easy as possible. We are all like-minded people carried away by space studies. It was easy for us to find a common language and to understand each other in a real way. Now, naturally, we have become great friends; what makes us akin is not only our profession, but also our common world outlook and our common goal.

At the moment medical and other specialists are selecting

* *Deputy head, Gagarin Training Centre, Hero of the Soviet Union, Pilot-Cosmonaut of the USSR.*

cosmonaut trainees in Bulgaria, Hungary, Mongolia, Rumania and Cuba. Lying ahead are new flights and new interesting experiments. Studying and exploring outer space is a process as infinite as the Universe itself.

Specialist Cosmonauts

In the near future I think there is bound to be a certain "specialisation" in our as yet rare profession. Those working for a long time in a Salyut-type spacecraft are capable of carrying out a wide spectrum of experiments in practically all fields of modern science, engineering and technology. Konstantin Tsiolkovsky, a great theorist and the founder of cosmonautics, justly believed that mankind will inevitably repeat in weightlessness the sum of technological and technical operations invented and mastered on the Earth.

We will have to pass through the stage of building gigantic structures in orbit: Sun-operated power stations, radio telescopes, and launching complexes for expeditions to other planets. There will have to be cosmonauts who specialise in assembly work, astrophysics or Earth studies.

Population census tells us there are more than 4,000 basic professions but as yet the profession of cosmonaut is not included. However, I believe that day will come.

The flight of Soyuz 28, with an international crew aboard, signifies the beginning of an important new stage in cosmonautics – a period of extensive international cooperation in studying and exploring outer space.

A COMPARISION OF VARIOUS ASPECTS OF THE MANNED SPACE PROGRAMME

By John H. Fadum

Basically the Mercury and Vostok spacecraft were designed to carry one man or woman in Earth orbit to determine to what extent and how well a person can function in space. Can a person carry out useful tasks in a spacecraft, or must he go along merely as a passenger? (In fact, in the early days the Mercury spacecraft was referred to as "the can with a man inside").

The two-man craft – Gemini and Voskhod – were designed to function with a two man crew, and, while the Mercury and Vostok spacecraft were designed to fly ballistically, with a pilot serving more as a systems monitor and guinea pig than anything else, in Gemini he was able and expected to *fly* the spacecraft. Mercury 4 (V. I. Grissom ("Gus"), 21 July 1961) showed that the spacecraft was more than simply a can with a man inside – Grissom changed his orbital plane and controlled his landing ("splashdown") point.

The two- and three-man Soyuz has served as an extension of Voskhod and also as a crew ship in connection with the orbiting space laboratory Salyut, while Apollo is also a three-man ship and has served for both Earth-orbit flights (Apollo 7, 9, ASTP), and Lunar flights (both Lunar orbit and Lunar landing) (Apollo 8, and Apollo 10-17). It was also used for the Skylab space station, formerly known as Apollo Applications.

While all this is very important (particularly the Apollo Moon landings), the most significant space venture so far has been the Gemini programme, since it has been concerned with a multi-man ship performing extensive orbital manoeuvring and rendezvous and docking with another space vehicle. Also, the Gemini spacecraft allowed one crewman to make extra-vehicular activity (EVA) while his spaceship was still being flown by his crewmate.

The usefulness of man in space in addition to machines was shown clearly by the Gemini space programme. Gemini 8 (Neil Armstrong and Dave Scott) had to be brought down manually after less than eleven hours of flight time because of a faulty thruster causing the spacecraft to tumble out of control, and Gemini 12 had to be placed in orbit by Buzz Aldrin and James A.Lovell because the automatic radar lock failed.

Although the main emphasis of the Apollo programme was the landing of men on the Moon, an essential part of Apollo was space rendezvous. The final idea NASA used for going to the Moon (Lunar Orbit Rendezvous) entailed having the actual Mooncraft (the Lunar Module,or LM) separate from the main spacecraft in lunar orbit, land on the Moon, then rendezvous and dock with the Moonship for the return flight, after crew transfer and discarding the now-useless LM. An earlier idea, favoured by such notables as Wernher von Braun and Robert A. Heinlein, was EOR (Earth Orbit Rendezvous), wherein the Moonship was launched into Earth orbit to rendezvous with previously launched tankers.

Perhaps the most important piece of writing on space rendezvous is the MIT Doctoral Thesis of Edwin E. "Buzz" Aldrin (who was on the first lunar landing): "Line of Sight Guidance Techniques For Manned Orbital Rendezvous" (MIT, 1963). This is a very detailed technical work, which Aldrin describes in "Return to Earth" (Random House, 1973) as "...more significant than my part in Apollo 11."

In a memorandum dated 4 April 1966, Assistant Director for Flight Operations Christopher C. Kraft says: Mission planning for a complex operation such as rendezvous must be carried out well in advance of the actual mission.... (It) would be difficult to find anyone who contributed more in the area of flight crew activity.... than Major Aldrin.

....Major Aldrin almost singlehandedly conceived and pressed through certain basic concepts.... without which the probability of mission success would unquestionably have been considerably reduced. The most striking example of this was his recognition that complete dependence on flawless operation of the basic spacecraft rendezvous guidance system was unnecessary and would be foolhardy...."

Future space missions will have their own risks and requirements. However, as long as one space vehicle will need to meet another – be it another spacecraft, a satellite, or a space station – these basic rendezvous techniques must be used. These techniques were developed and perfected during the Gemini series, and it is for this reason that Arthur C. Clarke [in "Beyond Apollo," Epilog to the book *First on the Moon*, by Armstrong, Collins and Aldrin (Little-Brown, Boston, 1970)] placed emphasis on "....the brilliantly successful Gemini flights of the mid-60's." He wrote: "These – and their Russian Soyuz counterparts – are perhaps a better guide to future space operations than the Apollo mission...."

LIVING IN SPACE AMERICAN STYLE

An interview with Joseph P. Kerwin, M.D.

With Soviet medical experts making a full examination of Lt. Col. Yuri Romanenko and flight engineer Georgi Grechko after their record-breaking endurance mission aboard the Salyut 6 space station, we thought it appropriate to recall some of the reactions of the U.S. Skylab astronauts who conducted 28, 59 and 84 day missions in 1973-74. During a five-day visit to the Johnson Space Center in Houston, Texas last year Mario Mutschlechner of Mexico City obtained this interview with Joseph P. Kerwin, M.D., the Skylab 2 science pilot.

Joseph P. Kerwin. *NASA*

MM: *Dr. Kerwin, what does it take to live in space? I had the opportunity to see your films, to see how you moved about there and it was just beautiful. You had become used to weightlessness – at first you had problems with it and then adapted to it.*

JK: One gets used to weightlessness very quickly, a week, ten day at the most, and you find yourself feeling so at home in this weird environment where all you have to do is push off and float, that you almost have trouble remembering what gravity is like. At least, that was my experience. All nine of us in Skylab adapted to it very quickly and it became a routine. Mostly, it's a marvellous feeling. There are some uncomfortable aspects to it, and if you have read the medical reports you know what those are: you feel stuffy in the head and you feel sleepy at times, because you are not using your muscles very much.

MM: *That is why you did all the exercises on board. This is something I would like to get into later, I mean: what happens physiologically?*

JK: A lot of very interesting things happen physiologically and we don't know the long term effect of them. We have investigated nine human beings, all middle-aged males whose physiology is very stable. There are not growing, they are not aging in particular, and we looked at them at most for one threehundreth of a lifetime or so, a small fraction of a lifetime. I don't know what the effect would be on infants and growing children. I don't know what the effect would be on sick individuals; I can speculate, but that's all we can do right now.

MM: *That's what I wanted to ask you. To speculate about a few of these aspects, you mentioned some already. For example, well, let's put it this way: Wernher von Braun believed that within this century a child would be born on the Moon. This was his speculation. Now, if you would speculate about its growth, its physical appearance and its difficulties to return to Earth, what would you say?*

JK: I think that a child.... we are in total ignorance here. Let me look back for a moment some 17 years to 1960 when we had planned to put a man in space but had not yet done so. The medical journals were filled with articles about the effect of weightlessness on human beings and there were many cries of alarm. Even 15 minutes might be too much, there would be various weird psychological phenomena that would happen. The individual would be unable to swallow and digest because of the absence of gravity. He might be unable to eliminate waste products. In fact, an Air Force doctor at that time did an experiment in which he took about 10 subjects, who were not pilots, and put them in a fighter plane, and when it did a parabolic flight of 30 to 40 seconds (of weightlessness) he asked them at the peak of the parabola to urinate into a bag and he found that half of them couldn't do it. The poor people were terrified, you know, they didn't know what was going on, and he wrote this up in an article and said: "Obviously we are going to have a serious problem with urination in weightlessness." Well, how wrong can you get? You're extrapolating from a little bit of data and you tend to draw a straight line and that's never right.

MM: *But if you extrapolate from your experience – you spent 28 days in Skylab and the third crew spent 84 days – don't you think that weightlessness is a plus?*

JK: Weightlessness is a plus in a few aspects. In locomotion certainly it is a plus; in the utilization of volume in spacecraft it is a plus, because you can sit on the ceiling as well as on the floor, and therefore a given volume seems larger when you're weightless, because you can utilize the space.

MM: *The multiple docking adapter was built that way (cylindrical, without floor or ceiling).*

JK: Yes, and it's funny: some of us liked it very much and some of us hated it.

MM: *Oh, really, for what reason did they hate it?*

JK: They hated it, because it was difficult to orient oneself to a particular section of it when you first entered it. If you entered it from another compartment you never knew where you were until you looked around for a minute and sighted

one or more piece of apparatus in it and then your mind would orient. You could go into it and you wouldn't know which way you were going to be pointed, you see! You don't remember that, because gravity is not giving you any clues. And that bothered a few of us and others it didn't bother at all. Some of them liked the downstairs compartment of the workshop better, because it was oriented like a series of rooms, like a one gravity environment and it was much easier to orient oneself, but that's a minor thing. O.K., weightlessness is an advantage in moving around large masses. You know, we had experiments that weighed 200 pounds, cameras like the ultraviolet camera we had put into portholes. In training on those cameras on the ground we had to have two or three helpers, in weightlessness you could do it with three fingers, just take your time, everything is easy and fun! Now, there are some drawbacks to weightlessness too: liquids don't behave, they don't stay in glasses or cups and special arrangements are therefore necessary for eating and for elimination. In repairing items, particularly where you have to take a mechanism apart, clean something and then put it back together again, it's a dreadful nuisance handling the little screws and nuts and bolts and pieces. You need some sort of special table to put them on that will keep them in place.

MM: *And special clothes with many pockets?*

JK: Maybe, yeah, it's easy to lose things up there, and that's a minor annoyance. Now, physiologically I don't think you can say that weightlessness is an advantage to the oragnism. At most you can say that it's a stress that the organism can adapt to without any obvious penalty or permanent physical damage. So far, as we have seen, in 84 days a lot of changes took place, but all the changes have been reversible. Now you ask me to speculate and I would speculate as follows: that if an organism, whether this be a human being or an animal, particularly a higher organism like a mammal, which has evolved in gravity and has many body systems that are adapted to gravity specifically, the muscular pump in the legs that returns blood to the heart and the valves and the vestibular apparatus and all the neural nerve connections are adapted to gravity. I think that if you raised a generation, or several generations perhaps, of such animals in weightlessness, that they would undergo much more profound changes than we've seen in these very short periods of time with adult animals. Exactly what form they would take, I don't know. Physically the muscles would probably change a great deal. Certain muscles would atrophy almost to the point of non-existence, others wouldn't change very much. The bones might be quite different, they might not calcify at all, who knows? Which would be weird!

MM: *They would be taller, maybe?*

JK: They might be taller, they might, yes: Perhaps more profound than that would be the neurological changes or the functional changes in the connection within the brain and the spinal cord, between the semicircular canals, the eyes and the muscles of the body. You know when we ride a bike or even walk downstairs all these things play together with reflexes to keep our balance and keep us pointed straight and to allow us to track a moving object with our eyes. All those adaptions would be totally different in such an individual, and therefore I believe that such an individual may have a great deal of difficulty. It might be impossible to readapt to Earth.

MM: *Yes, that is the one big problem (the readaptation to one-g) obviously. That is also the reason why you trained so much, why you did so much physical exercise on Skylab?*

JK: Yes, it turns out that it probably is not very important how much exercise you do before you go, but you should do exercise regularly once you are there to protect the large muscles of the thigh and the calf and the back from atrophy. I didn't quite agree with Dr. von Braun. He postulated a baby being born on the Moon. The Moon has gravity, not much, but some, one sixth. And that might be enough to prevent most of these changes from taking place. So I would be speaking of a space station in orbit rather than a colony on the Moon.

MM: *Speaking of space stations, the few concrete plans that exist so far all incorporate the idea of artificial gravity for the living quarters of the people. There will be different industries and these industries will be geared to different gravities, from zero-g, which is an incredible advantage for certain industries, to gravities of maybe several g's, but man is always supposed to live in one-g. I guess the main reason for this is that these people want to return to Earth and if they would be living in zero-g for a year or two they would have problems when coming back?*

JK: Possibly yes, but these designs basically come from ignorance. It would be a great advantage in terms of weight and structure and so forth to design an enormous space station that didn't have to rotate to produce artificial gravity. There are two kinds of space stations being talked about: one is the enormous habitat with 10,000 people, agriculture, industry, the wheel-type or cylinder-type. Those indeed use artificial gravity. NASA's own thinking is much more short-term. We envision in our studying, although we have no plans, to build something like that (a zero-g modular space station in Earth orbit) which is a station in that it is permanent, but the crews can be rotated for three months at a time or six months or whatever is convenient.

MM: *Well, I suppose there are plans that will still be realised within this century?*

JK: Oh yes, I am sure, I am almost certain of that! We could have something like that up in 10 years if the Shuttle is successful and we would like to for a variety of reasons. But this space station design does not utilize artificial gravity, it's a zero-g space station and it utilizes all the conveniences we talked about plus the fact that if you were going to do anything in space you either need a stable platform for pointing cameras and telescopes, or you need weightlessness itself for doing medical research, for materials processing and all that sort of thing. If you have to have the zero-g portion plus a rotating one-g portion your engineering problems multiply. So our plan is to go to zero-g, not to keep the crews up for long periods of time, but to approach that a little at a time.

MM: *Based on your experience in Skylab, what should be done concerning habitability and leisure time facilities in relation to a space station of this type?*

JK: Our experience in Skylab says that leisure time facilities are not a problem for durations of a few months, because the greatest recreational facility in the world is the window! If you get tired doing somersaults you go to the window, with a map, hopefully, and you learn about Mother Earth and that's fascinating! I don't think a lot of trouble has to be taken with recreation. Habitability is a little different. If you have people up there on a more or less routine basis and there are few of them they're going to get bored from time to time, they're going to get on each others nerves just as any small group of people would if you put them in an isolated place and say: "You got to stay here," and there is no chance to go to a movie, to be in a crowd, to meet people

or even to be by yourself if you want to. So I think that the size of the crew should be considerably larger than it was in Skylab to give more variety, more social contact, and at the same time, better provisions for privacy should be provided. From the social point of view and from the simple point of view that on Skylab it was very quiet.

MM: *Very quiet?*

JK: Very quiet! And if one person got up at night to go to the bathroom he usually woke up both of his crewmates. Now, to use a space station effectively some work should be going on in it all around the clock. And you need to simply design it so that that can happen, while the people who are asleep aren't bothered by this.

MM: *That, I think, can be done very easily in a space station of this design, a modular design, where you have people working in one module and sleeping in the other and so on.*

JK: It can be done, sure! Of course the engineers' tendency is to build it as cheaply as possible by using space for multiple purposes as much as they can, and that defeats the habitability, because they will want to have bathrooms and the kitchens and the sleeping facilities and the main control consoles and all of that just as compact as possible. And we keep saying: "Not quite so much! Spend a little more money and do it right!"

MM: *Well, Skylab was the largest space station and will remain the largest for some time to come. That was the great advantage you had. Hopefully this will be repeated some time in the not too distant future!*

JK: I'm sure it will!

MM: *You were the first people, who had a shower, and you had all this space!*

JK: Yes, just lucky, just because we had that piece of equipment lying around (*the S-IV B stage – Ed.*) and decided to use it.

MM: *And that was, I think, very important in relation to physiological studies, in relation to motion?*

JK: It gave us an opportunity to study that, and of course, it was a delight for the crew to have all that volume in which to move around.

MM: *Thank you Dr. Kerwin.*

BIS DEVELOPMENT PROGRAMME

PROGRESS REPORT – IV

OUR NEW HEADQUARTERS BUILDING

Early in April a start was made in taking off the garish yellow facing bricks on No. 27, South Lambeth Road, to make possible the installation of new windows, the deletion of an existing door and the eventual matching of the facade to that of No. 29.

At the same time, the opportunity was taken to build up new piers to take the replacement windows and to cut out all the defective brickwork in the wall of No. 29.

With all this banging going on, no-one noticed the knocking out of the rear brick windows taking place at the same time, which were also then given new supporting piers to take replacement windows.

Unfortunately, a considerable snag emerged with the exposure of the fronts of Nos. 27 and 29, since it was discovered that the foundations were not adequate to support the new brick-fronted "face."

As a result, work was held up while the front was excavated to enable the original foundations to be underpinned, with consequent delay and additional expense, expected to run to about £1,000. There was also a further requirement brought about by a change in the local Building Regulations making it necessary for us to install several additional drainpipes.

In the meantime, work went ahead in bricking in the old fireplaces and taking out the old mortar between the bricks of No 27, ready for re-pointing. Also, with the onset of good weather, an opportunity emerged for the roof joists (previously covered with plastic sheeting) to dry out, and so enable the two new roofs to be put on.

While all this was going on, considerable care had to be taken to extract the old woodwork around the windows of No. 29, which have to be preserved, besides attempting to save the moulding around the walls and the ceiling boss. The stairway, however, unique for the period, was too far gone to be saved, so a new stairway, moulded in exactly the same style as the original, will be needed to replace it.

An attractive ceiling boss in No.29 which we will endeavour to save.

No. 29 ("the house") was built in the late 19th century and is one of the very few remaining examples of this type of Period Architecture: this is the reason why the Greater London Council, Historic Buildings Commission, have made a Preservation Order on it, and why a number of its features, including its windows, facade and the front railings, all need to be preserved.

As a matter of interest, an illustration of an identical house appears as the frontispiece of *A London Family* by M. Vivian Hughes, Oxford University Press, 1946.

VENUS CALLS AGAIN

By Heikki Oja*

Introduction

Nineteen Seventy Eight should mark a major milestone in the exploration of Venus. A greater number of craft than ever before is planned for this year. If all goes well, in December we shall have three orbiters around the planet, the atmosphere will be probed at seven different points, and at least two spacecraft will function on the surface.

Four New Vehicles

The four new vehicles are two American Pioneers and two Soviet Veneras. The Pioneers have already received extensive coverage, in *Spaceflight* [1]. One of them, Pioneer 12, already on its way to Venus, will become the first American orbiter of the planet. It has among other instruments a simple side-looking radar to map the cloud-covered surface.

The second American spacecraft, Pioneer 13, to be launched in August, consists of five different vehicles. The mother craft "bus" will make measurements in the uppermost part of the atmosphere. Long before that, however, four entry probes will have been separated from the bus to enter the atmosphere of Venus at four different points. They are to make measurements during their descents. The entry probes are planned to withstand the impact on the surface, but not the 500-deg C temperature. So the probes will be destroyed soon after reaching the surface.

Soviet Successes

Soviet exploration of Venus has met with great success. Venera 4 made the first measurements in the planet's atmosphere in 1967. It was followed by Venera 5 and 6 in 1969. Venera 7 was the first spacecraft to reach the surface of another planet intact, in 1970. More information from the surface was obtained from Venera 8 in 1972. These probes confirmed the high temperature and pressure readings at the surface. Venera 8 made the first measurements on the day-side of the planet, and found there is enough light on the surface to take photographs. The first photographs were then obtained by second-generation Venus craft Venera 9 and 10 in October 1975. Both of thease vehicles consisted of an orbiter and a landing probe. The orbiters functioned around the planet for several months, and the landers gave information at two different points of the planet's clouds, atmosphere and surface. Each of them functioned for about two hours, one hour descending on the parachute, one on the surface.

Venera 11 and 12

It is known that the Soviet Union plans to launch new Venera vehicles this autumn [2]. To find the launch and arrival dates of Venera 11 and 12 I have drawn diagrams of the coming "launch window." This method is similar to that explained in my earlier articles [3].

The Soviet Union has consistently chosen the trajectories of its planetary probes very near the optimum launch dates.

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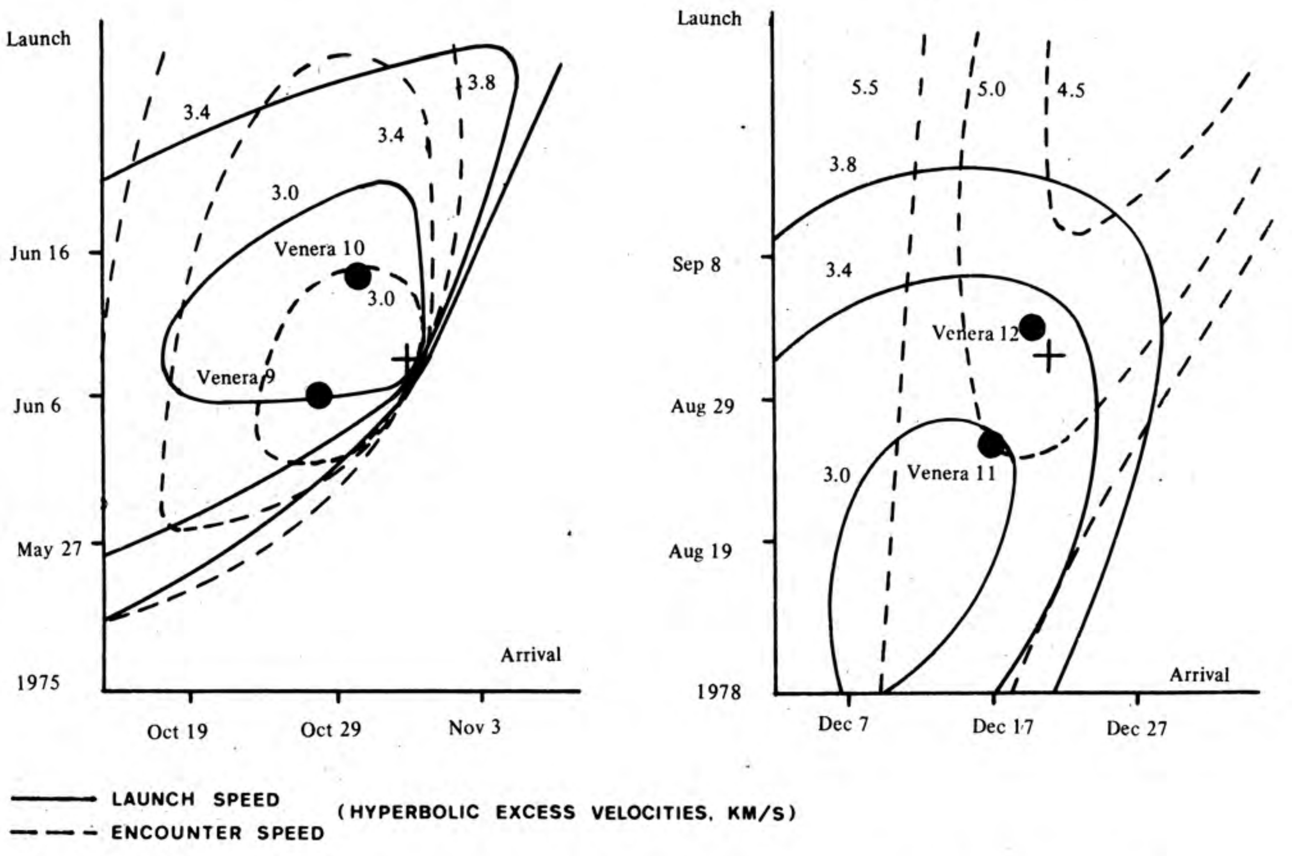


Fig. 1. Diagrams of the Venus launch window in 1975 and 1978. The contours give the launch and arrival velocities, and the corresponding dates are given on the axes. The crosses represent the optimal (minimum energy) trajectories, according to Russian calculations [4]. Venera 9 and 10 are shown on the left figure, and estimated places of Venera 11 and 12 on the right one.

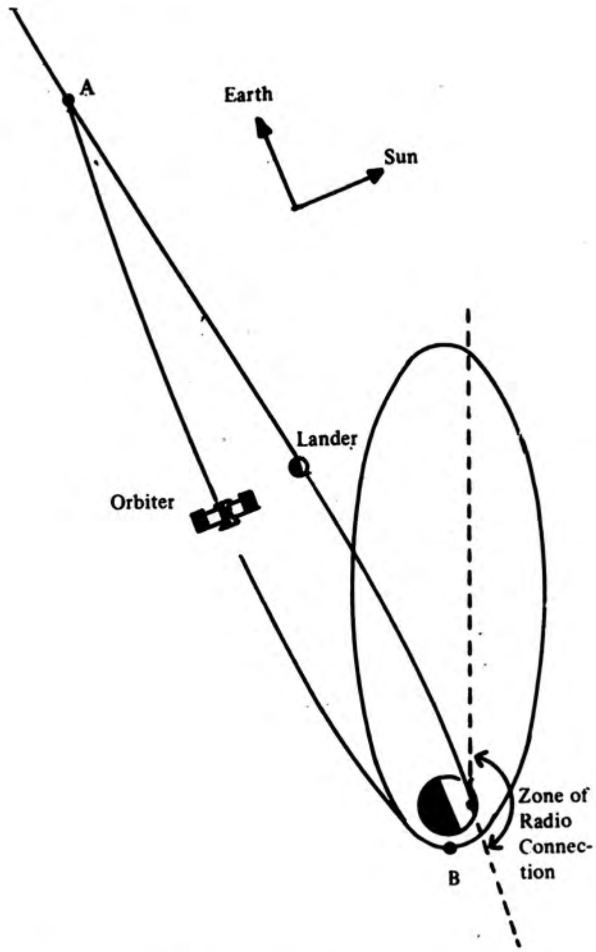


Fig. 2. Trajectories of Venera spacecraft near Venus. The lander is separated from the orbiter at point A some 48 hours before landing. The orbiter makes a course correction, and two days later, brakes near Venus at point B to achieve a high elliptical orbit around the planet. The lander at the same time makes an entry into the atmosphere on the day-side of the planet, and after the descent, a soft landing on the surface. The trajectories are planned so that the orbiter can receive signals from the lander for many hours after the lander's entry, and transmit them to the Earth. (Drawing modified from *Zemlya i Vselennaya*, No. 5/1976).

For example, we see from the diagram of the 1975 launch window (Fig. 1) that Venera 9 and 10 were launched within a week of the minimum energy trajectory.

If the same pattern is followed this year, the launch and arrival dates of the new Veneras can be estimated. They are given in the table below, and compared with the dates of the U.S. Pioneer craft.

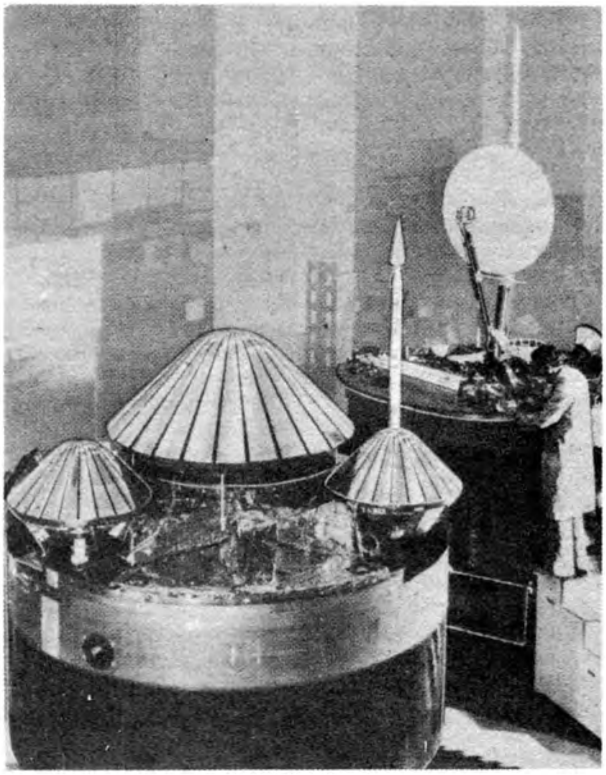
Spacecraft	Launch	Arrival
Pioneer 12	May 20 - Jun 10	About Dec 4
Pioneer 13	Aug 8 - Sep 3	About Dec 9
Venera 11	Aug 24-28	Dec 15-19
Venera 12	Sep 1-5	Dec 18-22

Pioneer 12 is launched along a longer trajectory than the other craft. This trajectory has a very low arrival speed near Venus, which makes it easier to insert the craft into orbit around the planet.

We see that Venera 11 and 12 arrive near Venus about a week later than their American counterparts. It is probable that the new Veneras are similar to Venera 9 and 10. Thus their weights are about 5000 kg, of which the landers weigh some 1600 kg.

Their tasks are expected to be principally the same as Venera 9 and 10 three years ago. The orbiters will make observations from orbit, and the landers will study the clouds, atmosphere and surface Fig.2.

The landers will probably obtain photographic panorama at two new points on the surface of Venus. It is also possible that they will photograph the ground during the last stages of their descents, from some hundreds or tens of metres above the surface. Venera 9 and 10 revealed that there is enough light near the surface for this; the light on the day-side of the planet is comparable to that on a cloudy day on Earth.



VENUS-BOUND SPACECRAFT. The two Pioneer Venus missions employ an Orbiter spacecraft (rear) launched in May, which will send back daily radar pictures of the planet, and a Multiprobe spacecraft (foreground) scheduled for launch 7 August. The latter will eject four cone-shaped probes (one is hidden by probe at centre) to return scientific data on the Venerian environment. Both will arrive at Venus in early December 1978.

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For results of Venera 9 and 10, see e.g., *New Scientist* 20 January 1977 and *Icarus* April 1977.

ASTEROID CHIRON - THE FIRST OF A FEW?

By Anthony T. Lawton

Introduction

Chiron, the name given to an object discovered by Charles T. Kowal on 1 November 1977, has been examined in greater detail. Two recent papers consider it to be the first of at least one new family of asteroids. This article summarises these findings, and suggests that they may have important parallels elsewhere in the Solar System.

Orbit of Chiron

When first announced, some doubt existed regarding the true nature of Chiron, and in addition the orbital elements seemed somewhat uncertain. After further work, the object has now been established as an asteroid with a diameter between 50-320 km, the uncertainty being due to the true nature of the surface – at present unknown. If it is frozen "ice" (water, ammonia, methane) as is Europa (third satellite of Jupiter) then the albedo (reflectance) is high and the smaller diameter is applicable. On the other hand if it is covered with dust or carbonaceous debris as possibly are Phobos and Deimos, then the diameter will be the larger value. Only time and patient measurement of the polarisation and absorption spectra of the reflected light will give further clues.

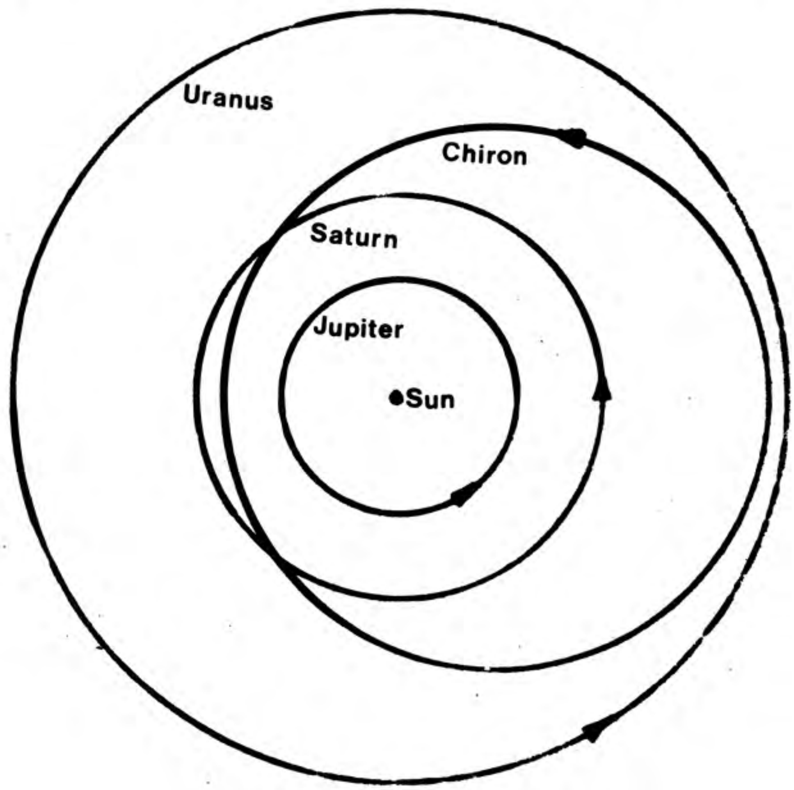
Originally, the orbit of Chiron was thought to be between Saturn and Uranus, and in a further discussion [1], the belief was expressed that perhaps this body was unique and in an orbital resonance condition with other major bodies. However, since its discovery and announcement, there has been a concerted search of old photographic plates and, as has happened previously in other cases, it has been photographed several times and not noticed. No fewer 30 photographic images have been found, the oldest dating back to 1895! Kowal is therefore to be congratulated on almost immediately recognising its true nature. The orbit has been slightly modified; it crosses that of Saturn (Fig. 1).

This later study has enabled Robert Connon Smith of Sussex University, and David W. Hughes of Sheffield University, to suggest further experiments which would yield additional information. Their work has been published in two recent articles in *Nature* [2, 3].

Smith believes that Chiron is one of the larger members of a family of asteroids which has been captured by Jupiter or Saturn and flung into its present orbit. The eccentricity of this orbit is 0.38 and the inclination 7°, parameters which are consistent with ejection – capture phenomena. Since the orbit of Chiron *crosses* that of Saturn, Smith considers this to be consistent with comparatively recent capture and ejection action by that planet.

He then suggests that there should be a belt of such objects between Jupiter and Saturn, these objects would be less than magnitude 15, and hence more difficult to detect. Again by a repeat process of capture and re-ejection one might expect a smaller belt of asteroids between Saturn and Uranus. Smith then goes on to consider the number of major asteroids between Jupiter and Saturn and suggests that there should be 50 such objects above magnitude 15 and approximately 300 bodies with magnitudes up to 15. These could well be orbiting faster than Chiron and therefore possibly easier to detect, and on this basis Smith suggests a systematic and detailed search for such bodies.

Although capture and re-ejection would theoretically produce a small group of major asteroids and a slightly larger number of minor ones, Smith points out that such a system violates Bode's 'Law' and therefore one could not expect to find a full belt between Saturn and Uranus such as exists between Mars and Jupiter. The number quoted (40) represents a quasi-stable state between the numbers ejected into the system from the Jupiter, Saturn and the Mars, Jupiter belts, and then either flung back, or perman-



Orbit of Chiron

ently captured as moonlets by the outer planets. Hughes cites the possibility of Phoebe (the present known outermost satellite of Saturn) as an asteroid captured from this quasi-stable belt, whilst the eight outer satellites of Jupiter may have been gravitationally trapped from the Jupiter, Saturn belt.

To this I would add the rider that future space telescopes may well detect additional satellites of both Saturn and Uranus. Already the latter has been found to possess a ring system similar to Saturn but smaller in scale. The outermost known satellite – Oberon – is large (approximately 2,500 km) and presumably evolved with the planet. The discovery of rings and the probability of a Saturn-Uranus asteroid belt makes it virtually certain that the planet has additional captured satellites. The use of space telescopes or perhaps the systematic search by Kowal may reveal some of them even though they will be faint (visual magnitude 19-20). The same also applies to Saturn which although the subject of many careful searches may still have one or more as yet undiscovered satellites barely 30-50 km in diameter.

Close Encounters

Dr. Brian Marsden of the Smithsonian Astronomical Observatory reports that occasionally Chiron has fairly close encounters with its giant planetary neighbours. In 1664 it passed within 0.1 A.U. of Saturn, and in or around 500 BC it passed within 0.2 A.U. of Jupiter! This perilous proximity coupled with the high inclination is the basis of the Saturn ejection hypothesis mentioned earlier.

This closely parallels the Lyttleton/Kuiper idea that Pluto is not a true planet but a runaway satellite of Neptune, ejected from the gravitational pull of that planet by a close encounter with Triton, Neptune's only major satellite. The parallel is drawn from the orbital resemblance of Chiron to Pluto in terms of inclination, eccentricity, and crossing the orbit of neighbouring giant planets. There is a further parallel in that the orbital motion of both Triton and Phoebe are retrograde – a possible consequence of the second body in a slingshot ejection encounter.

There is one final comment I would make on this interesting addition to the Solar family. It is small, not very massive and easily perturbed. Furthermore, it has a reasonably short orbital period (approximately 51 years) and can yield perturbation data with high order accuracy in a relatively short time. Since it is easy to photograph and pinpoint accurately, any deviation may be quickly and accurately checked. Chiron could therefore be the key to the almost 50 year old puzzle as to whether Pluto *really is* the planet responsible for the observed and recorded perturbation of Uranus and Neptune, or just a lightweight interloper.

We may finally be properly on the trail of the 10th planet*

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* *The theory that a tenth planet circles the Sun unseen beyond the orbit of Pluto is to be probed anew by Soviet astronomers. Computer experts at the Soviet Institute of Theoretical Astronomy will analyse the paths of certain far-ranging comets which may be perturbed by such a planet. When the first of these approaches the Earth in 1982, slight changes in the comet's path may provide a clue to the planet's position. Attempts then will be made to locate it with powerful telescopes. Ed.*

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SATELLITE DIGEST-118

A monthly listing of all known artificial and spacecraft, compiled by Robert D. Christy. Information sources include the Royal Aircraft Establishment at Farnborough, NASA, Novosti and both the popular and specialist press. For a more detailed summary, see Satellite Digest – 111, January 1978.

Continued from July issue, p. 276]

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Soyuz 28 1978-23A	1978 Mar 2.644 7.929 days (R) 1978 Mar 10.573	Sphere + cone-cylinder + antennae 6570?	7.5 long 2.3 dia	192 251 334	246 306 353	51.63 51.62 51.62	88.82 90.02 91.35	Tyuratam-Baikonur A-2 USSR/USSR (1)
Molniya-1AQ 1978-24A	1978 Mar 2.92 12 years?	Cylinder-cone + 6 panels + 2 antennae 1000?	3.4 long 1.6 dia?	617 489	40739 39741	62.82 62.84	738.14 717.79	Plesetsk A-2-e USSR/USSR (2)
Cosmos 992 1978-25A	1978 Mar 4.32 12.9 days (R) 1978 Mar 17.2	Sphere + cylinder- cone? 5500?	5 long? 2.2 dia?	203	323	71.34	89.79	Tyuratam-Baikonur A-2 USSR/USSR
Landsat 3 1978-26A	1978 Mar 5.75 100 years	Truncated cone + 2 panels 960	3.0 long 1.45 dia	900	918	99.14	103.21	WTR Delta NASA/NASA (3)
Oscar 8 1978-26B	1978 Mar 5.75 100 years	Cuboid 27	0.4 each side	903	917	98.99	103.23	WTR Delta NASA/NASA (4)
Cosmos 993 1978-27A	1978 Mar 10.45 12.7 days (R) 1978 Mar 23.2	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	171 170	340 393	72.86 72.85	89.63 90.15	Plesetsk A-2 USSR/USSR (5)
Cosmos 994 1978-28A	1978 Mar 15.66 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	980	1011	82.93	105.05	Plesetsk C-1 USSR/USSR (6)
1978-29A	1978 Mar 16.78 6 months	Cylinder 13300 fuelled?	15 long 3.0 dia	160	240	96.43	88.52	WTR Titan 3D DoD/USAF (7)
1978-29B	1978 Mar 16.78 60 years	60?		639	645	95.83	97.59	WTR Titan 3D DoD/USAF (8)
Cosmos 995 1978-30A	1978 Mar 17.45 12.8 days (R) 1978 Mar 30.3	Sphere + cylinder- cone? 5500?	5 long? 2.2 dia?	217	235	81.34	89.05	Plesetsk A-2 USSR/USSR
Cosmos 996 1978-31A	1978 Mar 28.06 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	957	1010	82.93	104.80	Plesetsk C-1 USSR/USSR (9)
Cosmos 997 1978-32A	1978 Mar 30.00 <1 orbit (R?) 1978 Mar 30.07	Cylinder? 7000?	7 long? 2.5 dia?	195	210	51.60	88.48	Tyuratam-Baikonur D-1 USSR/USSR (10)
Cosmos 998 1978-32B	1978 Mar 30.00 <1 orbit (R?) 1978 Mar 30.07	Cylinder? 7000?	7 long? 2.5 dia?	195	210	51.60	88.48	Tyuratam-Baikonur D-1 USSR/USSR (10)
Cosmos 999 1978-33A	1978 Mar 30.33 12.89 days (R) 1978 Apr 12.22	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	174 172 185	352 324 330	71.39 71.39 71.39	89.79 89.50 89.69	Tyuratam-Baikonur A-2 USSR/USSR (11)
Cosmos 1000 1978-34A	1978 Mar 31.58 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	965	1012	82.93	104.90	Plesetsk C-1 USSR/USSR (12)
Intelsat 4A (F-6) 1978-35A	1978 Mar 31-98 indefinite	Cylinder + antennae 825.5	2.82 long 2.39 dia	549 35768	35949 35806	21.85 0.3	641.03 1436.1	ETR Atlas/Centaur Hughes/NASA (13)
Cosmos 1001 1978-36A	1978 Apr 4.63 10.87 days (R) 1978 Apr 15.50	Cylinder + panels? 7000?	7 long? 2.5 dia?	200 195 306	228 291 322	51.62 51.64 51.60	88.72 89.31 90.74	Tyuratam-Baikonur A-2 USSR/USSR (14)

Name designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payloads/launch origin
Cosmos 1002 1978-37A	1978 Apr 6.38 12.84 days (R) 1978 Apr 19.23	Sphere + cylinder-cone? 5500	5 long? 2.2 dia?	204	282	65.05	89.36	Tyuratam-Baikonur A-2 USSR/USSR

Supplementary notes:

(1) Carried the third crew to board the Salyut 6 orbiting laboratory. The crew consisted of the commander, Colonel Alexei Gubarev and cosmonaut researcher, Captain Vladimir Remek of the Czech Army – the first non-Soviet or non-American to fly into space. Soyuz 28 docked with Salyut 6 at 1978 Mar 3.715 and the crew transferred at 1978 Mar 3.83. Orbital data are at 1978 Mar 2.0, 1978 Mar 3.3 and 1978 Mar 3.9.

(2) Orbital data are at 1978 Mar 5.0 and 1978 Mar 6.0.

(3) Third operational US Earth resources survey satellite, which is an improved version of the previous two. Landsat 3 carries two sets of sensors, a multispectral scanner detects reflected and emitted radiation to obtain spectral signatures of various areas of the Earth; a return beam vidicon camera system provides photographic coverage. Landsat 3 also is capable of collecting data from remote sensors throughout the US which monitor the local environment. The final stage of the launch vehicle, in a similar orbit, carries a 34 kg experimental package designed to investigate the interaction between high voltage power systems and plasma in space.

(4) Latest in a series of satellites for use by radio amateurs, launch pick-a-back with Landsat 3. It carries two transponders using an uplink at 145.9 MHz and downlinks at 29.4 and 435.1 MHz.

(5) A manoeuvring engine separated during 1978 Mar 22; it is designated 1978-27D. Orbital data are at 1978 Mar 11.8 and 1978 Mar. 18.1.

(6) Cosmos 994 may be a navigation satellite.

(7) "Big Bird" type reconnaissance satellite.

(8) Supplementary payload launched along with 1978-29A.

(9) Cosmos 996 may be a navigation satellite.

(10) Two satellites launched with a single vehicle, probably recovered at end of first orbit. The flight is similar to that of Cosmos 881 and 882 (1976-121). There also may be a connection with Cosmos 929 (1977-66A).

(11) A manoeuvring engine separated during 1978 Apr 12, it is designated 1978-33C. Orbital data are at 1978 Mar 31.3. 1978 Apr 4.1 and 1978 Apr 7.1.

(12) Cosmos 1000 is a navigation satellite.

(13) US domestic communications satellite in geostationary orbit above 60 deg East.

(14) Cosmos 1001 may be connected with the development of a manned spacecraft. Orbital data are at 1978 Apr 4.8, 1978 Apr 6.0 and 1978 Apr 10.8.

Amendments and decays:

1978-15, a supplementary payload separated from Cosmos 988 during 1978 Feb 19, designated 1978-15F.

1978-16A, Fleetsatcom 1, add another orbit at 1978 Apr 14.0: 35753 x 35817 km, 2.7 deg, 1436. 1 min.

1978-17, the launch of this object may have occurred around 1978 Feb 25.2; the orbit may be as follows: 310 x 39000 km, 63 deg, 704 min.

CORRESPONDENCE

'Worlds Without End!'

In the month before he died Harry Ross had been re-examining some of the questions which have been raised in these columns concerning a 'BIS Society Motto.' He sent us these informal notes in April. Ed.

Sir, I first set out what the characteristics should be, as follows:

1... Apt.
2... Have panache.
3... Short in number of words, in both Latin and English.
4... Easily pronounced in Latin – roll off the tongue.
5... Fairly easily recognized in Latin.
6... Sound well in English.

I decided that the overriding requirement was terseness, to make it suitable for an insignia surround.

My first preference was an abstract from Tennyson's Locksley Hall – i.e., *In the foremost files of time.* However, on enquiring around various Latin scholars I found that the poetic content didn't translate well – even differed greatly. Several other of my selections suffered the same fate. In the end I have adopted as my first preference a suggestion by Max Wholey. It is:

1... WORLDS WITHOUT END = *Sine Fine Mundi* (Extra panache could be given by terminating with an exclamation mark).

I need hardly go much further, but the following are a few other possibilities, not in order of preference.

2... NO BOUNDARIES (In rephrase to the unknown and no limits) = *Sine Finibus ad Ignota* (per Max Wholey and associate).

3... THROUGH THE MIND TO THE STARS = *Ad Stellas Per Igenium* (per Max and associate).

4... From Lucretius (BC 65) per Max's associate LET IMMENSITY AND ALL THE VASTY DEPTHS LIE OPEN TO US = *Immensum Pateat Vasteque Profundum.*

5... From Oxford University source but my suggestion. THE IMPOSSIBLE IS TOMORROW'S CHILD. (What is now impossible shall be born tomorrow = *Quod Nune Impossibile Id Cras Nascetor*).

The following are possibilities from my own research:

6... TO THE STARS! = *Ad Astra!*

7... TRUTH IS MIGHTY = *Magna est Veritas*

8... I SHALL STRIKE THE STARS WITH MY UPLIFTED HEAD = *Sublimi Sidera Vertice* (from Horace).

9... TO INFINITY = *Ad Infinitum.*

10... CONCERNING ALL THINGS = *De Omnibus Rebus.*

11... THUS ONE GOES TO THE STARS (or may be understood as Such is the Way to Immortality = *Sic Itur Ad Astra).*

12... TRUTH CONQUERS ALL THINGS = *Vincit Omnia Veritas.*

I hope the foregoing will be useful.

H. E. ROSS

Water on Mars

Sir, I was delighted to read the article, "Martian Dust Storms – a Mechanism for Transportation of Life?" by G. Day (*Spaceflight*, March 1978).

The author wrote on p. 86:

"... conditions in basins near the equator might be best; pressure and temperature being higher there so that liquid water might exist..."

My comments refer to the stability of liquid water on Mars, a topic which has been the subject of some misunderstanding in the past.

In [1], the following statements can be found: For water to exist in the liquid phase in thermal equilibrium, the necessary and sufficient conditions are:

(a) that it be above the triple point temperature;

(b) that there be sufficient heat input to the bulk material to replace the energy extracted as latent heat;

(c) the vapour pressure above it must be the relevant saturation value for the temperature of the liquid;

(d) the vapour pressure gradient at the surface (of the liquid) must be zero.

Condition (d) occurs only in an enclosed volume, but quite rarely in natural environments. The conditions (a) and (b) can be met in certain favourable areas on Mars, but only during the time interval of highest insulation. An admixture of dust in the ice to be melted will reduce the albedo and augments the heat flux into the ice. An equatorial area is then not necessary to reach the melting point. During summer, a dark surface may reach 273°K at latitudes 50-60° south and ~ 40-50° north. Important is a rather low atmospheric opacity with a value of τ not greater than about 0.1-0.15. In this context, the Hellas basin is not a favourable area, since dust storms are very frequent in this region and the value for τ seems to be so high nearly every day throughout the year that the surface cannot reach the necessary temperature of 273°K.

Regarding condition (c) in Farmer's article and remembering the old and recent measurements of the water-vapour content of the Martian atmosphere, it is immediately evident that open bodies of liquid water in thermal equilibrium (or near it) cannot exist on Mars. Indeed, the maximum amount of ~ 100 μm precipitable water in the northern polar latitudes is in equilibrium with an ice layer at a temperature of 210-215°K, far below the triple-point temperature.

The mass loss of an exposed ice layer may, if the speed of wind near the surface is very high, approach the loss-rate in vacuum! A clean ice-layer of 1 cm thickness will then survive only about 15 seconds. The rate of vapourisation is reduced by the barrier to free evaporation which the atmospheric pressure presents. If evaporation is very low, the deposition of H_2O-molecules, due to diffusion of water-vapour into CO_2, is relatively low. As stated in [1], Mukherjee has postulated that a "stagnant layer," the layer of mixed CO_2 and H_2O-vapour molecules in contact with the ice surface, may be as thick as 1 cm; he concludes that in this most favourable case the evaporative loss may be as low as about 0.25 cm of ice per day.

Since the maximum insolation is only a few hours per day, an ice layer of 0.1-0.3 metres may survive the summer if it is in a low, sheltered location. But for a rather clean ice-layer the maximum solar heat flux may be too low to create a thick stagnant layer as a barrier for free diffusion from the liquid layer on the ice.

A possibility to augment the stability of liquid water on Mars is the introduction of water-soluble materials. Water-salt solutions can indeed reach very low temperatures before completely freezing. A mixture with about equal weights of H_2O and NaCl freezes at ~ 250°K, a mixture of 7 parts H_2O and 10 parts of $CaCl_2 \cdot 6H_2O$ freezes at about 224°K.

Small lakes of such concentrated brines do exist in Antarctica – they do not freeze during wintertime. Considerations concerning the existence of salt solutions on Mars had been quite academic until the recent soil analysis in *Chryse* and *Utopia*. The samples showed a certain amount of Cl, S, Ca and possibly Ba [2]. It was suggested that the Cl is in the form of NaCl and the S in the form of $MgSO_4$. Both minerals are water-soluble and there may be enough NaCl to depress the freezing-point at least to ~ 260°K. Such an aqueous solution can far more easily meet the condition of a thick stagnant layer. The problem to get an appropriate admixture of ice-particles and NaCl-particles remains, but due to the frequent dust storms, such mixtures can be formed. One can even speculate on the existence of big salt deposits; an enigmatic deposit (NaCl?) was found by Mariner 9 in an equatorial crater on Mars [3]. I have not heard so far of any measurements or photographs of this area obtained with the Viking orbiters. Spectral investigations will give strong indications of the nature of this enigma.

The authors in [2] suggested that aqueous solutions of NaCl-$MgSO_4$ should be used as a solvent in life-searching measurements in future missions!

In [1], Farmer gives a quantative estimate for the possibilities of the fusion of water in the case of an ice-layer covered by a layer of dust or in the case when frost is formed by condensation on the interstitial surfaces of the regolith. For small particle sizes and relatively low porosities of the regolith, the survival time for ice at the melting point is several tens of hours. The ice would melt and refreeze during the summer until it is finally dissipated. Farmer remarked that this persistence of milligrams of water per cubic centimetre of soil would be of some significance to the persistence of microorganisms.

In conclusion, it seems that water can exist under non-equilibrium conditions in a broad latitude band on Mars, in conjunction with dust covers, poroses in stones, and in the form of interlayer water in clays. It can never exist for more than hours or days as an open body. In certain circumstances, an open body of a saturated aqueaus solution may survive some weeks or even months.

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Asteroids and the Mass-driver

Sir, Your correspondent S. B. Kramer suggests [1] that the use of a mass-driver to move asteroids may endanger life on Earth, since the material ejected as propellant could survive passage through the atmosphere. In fact, the danger can be completely avoided by either of two methods. One can (a) choose an exhaust speed so high that the ejected material has escape velocity from the Solar System, or (b) crush it into particles small enough to be destroyed or slowed down in the upper atmosphere.

If method (a) is adopted, the exhaust speed w need only exceed the *difference* between the asteroid's speed at each point in the transfer orbit and the corresponding escape speed, since the material is ejected in the direction of motion. If the transfer orbit is a spiral, under continuous low thrust, this condition is most stringent at the Earth end of the orbit and is

$$w > (\sqrt{2} - 1)\, v_{cE} \sim 12.4 \text{ km/s}, \qquad (1)$$

v_{cE} being the Earth's orbital speed of about 30 km/s. It is then simple to ensure that the escape trajectory of the exhaust does not come near Earth.

Since a high exhaust speed is in any case desirable to reduce the mass ejected, we may expect method (a) to be adopted as soon as mass-driver engineering permits. The relevant equation is

$$w^2 = 2aL \qquad (2)$$

where a is acceleration in the mass-driver and L its length. If w = 13 km/s, choosing a $100g \sim 1$ km/s^2 leads to a rather unwieldy but possible $L \sim 85$ km; alternatively a = 1000g gives $L \sim 8.5$ km. (Kramer's estimates of specific impulse and implicitly of w are invalid, as he confuses the time interval between emission of one exhaust 'particle' and the next with the time taken to accelerate each 'particle').

If method (b) is chosen, there is no danger to the Earth, but one might worry about the effect on human activities in space. The important question here is "How much are we adding to the natural meteoric background?"

To answer this, consider a "worst case" example where a mass-driver with w = 5 km/s is used to deliver a million tons from the main asteroid belt to high Earth orbit. The velocity change for a low thrust transfer orbit is about 12 km/s = 2.4w, so that the total mass ejected is $(e^{2.4} - 1)$ million tons or about 10^7 tons. (In fact the operation would not be attempted with such a low w for this reason). By directing the exhaust a few degrees either side of the orbital plane, it can be spread fairly evenly through a flat ring of thickness $\sim 10^7$ km and inner and outer radii 1 A.U. and more than 3 A.U. The volume of the ring is about 10^{25} km^3, so the density of ejected material in it is $\sim 10^{-18}$ tons/km^3. The Earth, moving with a *relative* velocity of $\lesssim 30$ km/s and an effective cross-section of $\sim 2 \times 10^8$ km^2 allowing for gravitation, would therefore encounter at most some 6×10^{-9} tons/s or 6×10^{-4} tons/day of this material. But the natural infall of meteoric material on Earth has been estimated [2] as 10^3 tons/day. Thus even ten thousand such asteroid transfers add less than 1% to the natural background, surely an acceptable figure.

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The Vostok/Voskhod Family

Sir, The question of the design of the Voskhod spacecraft has come to the fore again with the display of the Cosmos biosatellite at the 1977 Paris Air Show. In the Correspondence column of the May issue of *Spaceflight*, John Catchpole speculates that the Cosmos vehicle is a development of Voskhod rather than Vostok. This is a reasonable point and I must admit that when I first saw the biosatellite, my reaction was very similar and at the time I expressed the

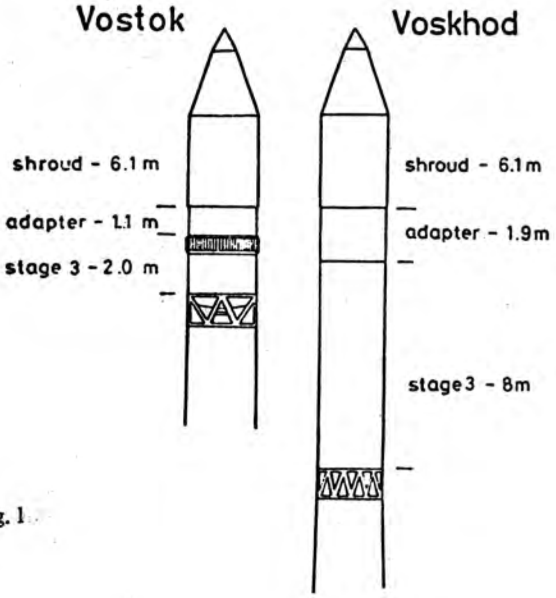

Fig. 1

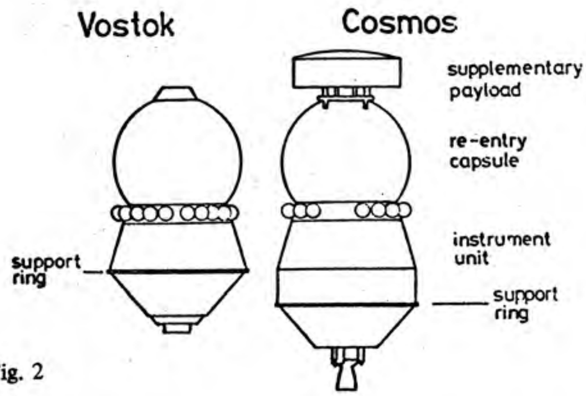

Fig. 2

same sort of view. However, when I wrote the piece for *Spaceflight*, I was beginning to have doubts and decided not to commit myself in writing [1].

Since then, I have searched through various publications to find photographs of Voskhod and its launch vehicle. This has resulted in some success and I have managed to measure the upper stage of the launcher and the aerodynamic shroud. The results are shown in Fig. 1 with the Vostok vehicle for comparison.

One thing that is immediately apparent is the same shroud seems to have been used for both Vostok and Voskhod, a good indication that the contents were similar. Photographs of the complete Vostok vehicle are readily available and a full sized replica stands outside the Space Pavilion at the Exhibition of Economic Achievements in Moscow. Measurement was therefore reasonably easy.

Measuring the Voskhod vehicle was more of a challenge. I had available one good photograph of the Voskhod 1 launcher [2] and several, in different publications, of the Voskhod 2 shroud along with parts of the final rocket stage. From these, I deduced that the total length of the rocket stage and spacecraft adapter was 9.9 m. Soviet data released in connection with ASTP [3] gives the length of the upper stage of the A-2 when used with Soyuz as 8 m. This leaves 1.9 m for the Voskhod adapter. Assuming that the Voskhod instrument unit rested inside the adapter in the same way as Vostok's, the indication is that it was longer because the Vostok adapter was only 1.1 m long (i.e. 0.8 m shorter).

Study of the biosatellite instrument unit showed that, in comparison with Vostok, it had been lengthened by the introduction of a cylindrical section approximately 0.6 m long and that the retro-rocket nozzle was slightly longer. It is tempting to assume that the longer Voskhod adapter was a result of using a biosatellite type instrument unit.

There is one pointer to the fact that this was not the case. It lies in the location of what I have called the "support ring" in Fig. 2. This ring is the point at which the spacecraft is attached to the upper stage of the booster. On photographs and models of Vostok it can be found at the base of the truncated cone immediately behind the re-entry vehicle. On the biosatellite it is located at the end of the additional cylinder furthest from the re-entry vehicle. The consequence of this is that, if a biosatellite type instrument unit was used, the spacecraft would still have fitted the Vostok shroud but the airlock of Voskhod 2, for example, would not have been accessible through the shroud in the manner indicated by photographs [2, 4].

The conclusions which may be drawn are that Voskhod could well have been provided with an enlarged instrument unit but it seems unlikely that it was of the type used by the biosatellite. This Cosmos vehicle represents one of the latest in a line of spacecraft which started with the pre-Vostok spaceship-satellites nearly twenty years ago in 1960. What has probably happened is that the basic spherical casule has been retained over the years with a variety of internal equipment. The instrument unit has undergone an evolution with new and modified equipment being installed as necessary to support specific types of mission. It is wrong, perhaps, to refer to recoverable Soviet satellites as "Vostok types." Voskhod derivatives," etc. What the Soviet Union possesses in fact is a standard space vehicle which, by suitable choice of onboard equipment, has been used as both single and multi-seat manned spacecraft, biosatellite, scientific satellite (e.g. Intercosmos 6), Earth resources satellite and military photoreconnaissance platform.

While discussing Voskhod, the photograph provided by Neville Kidger (also in the May *Spaceflight*) invites some comment. The launch vehicle shown is almost certainly an A-2 but without knowing the designation of the spacecraft at the side very little information can be gleaned from it. The most notable thing about the picture is that it seems to be laterally inverted! Somewhere along the line, a negative has been reversed. The only way to reconcile the relative locations of the porthole and the cable link to the outside of the capsule is to look at it in a mirror.

If the object is indeed a Voskhod, the possibility of it being Voskhod 1 cannot be ruled out on the grounds quoted by Mr. Kidger. In the words of the Voskhod 1 crew describing the flight, ".... In a minute, one of the *two* braking engines was supposed to fire. It did!...." [5]. However, he is correct in that it does not represent Voskhod 2 as the airlock would be on the side facing the camera.

Whatever the answer to the "What did Voskhod look like?" question, we are unlikely to know the complete truth until the Soviets decide to tell us.

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Mass of propellant necessary for a given ΔV imparted to relocate an asteroid.

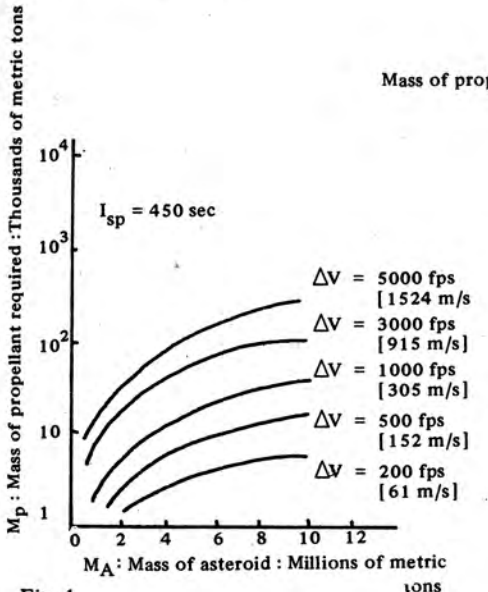

Fig. 1.

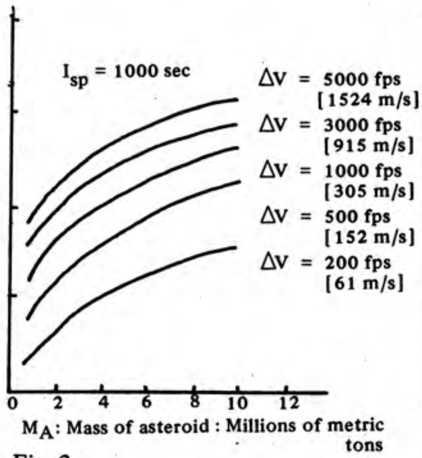

Fig. 2.

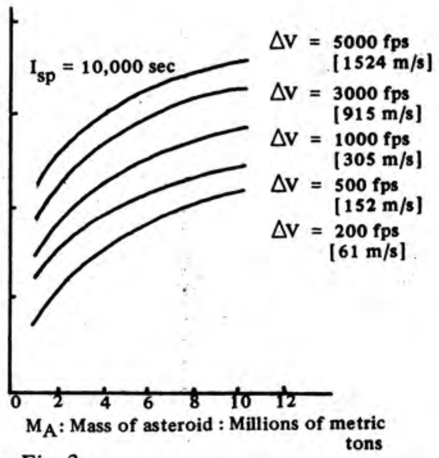

Fig. 3.

Problems of Asteroid Capture

Sir, Encouraged by the space colony-mass driver concept in which corollary ideas are discussed suggesting the use of captured asteroids (among other alternatives) as a source of supply for materials to feed either the manufacturing facilities of a colony or as a source of materials for constructing the colony itself, comments have been forthcoming supporting this idea [1]. I have emphatically rejected the suggestion for asteroid capture in rather general terms, but this subject demands examination in a more precise manner than expressed in my earlier comments or those of others [2, 3]. The results emphasise the great difficulty in bringing such a perception to fruition, even using very advanced propulsion methodology, i.e. engendering very high specific impulse.

To suggest capturing asteroids of the mass of Hermes, Icarus or Eros, which range in size from perhaps 2 to 35 kilometres is simply out of the question.

Hence, I propose a hypothetical Asteroid called K; it is 1,000 metres through its equatorial diameter, 500 metres from 'pole to pole' and takes the form of an oblate spheroid (volume = $V = [4/3]\pi a^2 b$, where a and b are the semi major and minor axes respectively). Since K will be mined for metals primarily, it will have been chosen for its high metallic ore content and thus have a density, say, of 5 grams per cubic centimetre. Further, by some miracle of choice we find that it takes only 61 metres per second (200 fps) to place it in an orbit around the Earth.

Given these characteristics K weighs in at 1.3 billion (1.3×10^9) metric tons. If the propulsion mechanism used to redirect the asteroid has a specific impulse of 450 sec (LOX/LH_2) it takes 19.5 million (19.5×10^6) metric tons of propellent to perform the activity. If a specific impulse of 1,000 sec. is available (nuclear?) then 7.5 million tons of propellent is required; 10,000 sec. (!) reduces the need to 0.84 million tons.

In these calculations I have considered only the *propellent mass at the asteroid*; neither the vehicles nor propellent mass to bring the asteroid propellent and its propulsion system to the asteroid have been considered. Quite evidently, reducing by ½ the size or the density – or both – of K doesn't offer significant aid in resolving the difficulty. Neither current technology nor any on the horizon is up to the task of placing K or anything like it in Earth orbit. So much for capturing asteroids for mining, alas!

Using the familiar rocket equation (as used in determining the propellent needs above

$$M_p = M_a \left[1 - e^{\frac{-\Delta V}{I_{sp} g}}\right],$$

where, M_p = propellent mass, M_a = asteroid mass, ΔV = velocity to redirect the asteroid, $g = 9.8\ m/sec^2$, I_{sp} = specific impulse; the propellent requirements for redirecting much smaller asteroids are shown in Figs. 1, 2, 3, for three different values of specific impulse and through a spectrum of five possible velocity requirements. The results are still dismayingly high especially when one recognises that the concommitant mechanisms for reaching the asteroid with such propellent have, again, not entered the calculations.

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3. Several private communications.

Naming Extraterrestrial Features

Sir, It is interesting to read von Puttkamer's article "On Humanity's Role in Space" (*Spaceflight*, February 1978) in conjunction with the review of the edited "Proceedings of the Sixteenth General Assembly of the IAU" (*Spaceflight*, May 1978, p. 194). The former stresses the role of space exploration in the expansion of the human spirit and imagination, while the latter describes the IAU's policy of distributing prosaic and Earth-bound names throughout the Solar System; e.g. "small craters on Mars will be named after cities and villages.... other features will be named after scientists, artists and composers and there are also some more traditional Latin names."

Out of all these, only the Latin names are likely to be original and fitting. That ancient silvery language is well suited to names for places on the Moon; thank goodness for Riccioli who, in the seventeenth century, named the lunar 'seas.' But as for the other names – they seem deliberately designed to reduce the sense of awe and wonder and 'otherness' with which the Universe is viewed. Looking

through the *Times Atlas of the Moon*, I came across a crater near the *Mare Frigoris* called Birmingham.

I wonder if any other readers feel as strongly as I do about this kind of thing. Terrestrial names are fine – for places on Earth. Personal names are fine – for people. But a new name for a new world should either be completely new, or be a mixture of old and new (a derivation of some kind); it should not be completely old. Of course, the greater the amount of imagination used, the harder it may be to form a consensus; but think of the drabness of the alternative! 'Voyager' will photograph four new worlds next year. We are in imminent danger of finding Clacton on Callisto and Guernsey on Ganymede.

ROBERT GIBSON,
Hemel Hempstead, Hertfordshire.

Soviet Space Shuttle

Sir, I read with some interest the report in the June issue of *Spaceflight* that a re-usable Soviet spacecraft was "drop-tested" from a Tu-95. (Milestones entry, 20 March). The correspondence columns of *Spaceflight* have recently contained a number of letters speculating on the so-called 'Kosmolyot' space shuttle, but the designation of the test aircraft throws more light onto the matter.

The Tu-95 is a large, four turbo-prop' bomber with a maximum take-off weight of approximately 154,220 kg [1]. The bomb load would be about 15,000 kg. Taking into account various modifications which could be made to lighten the airframe, the Tu-95/Kosmolyot combination would come nowhere near the weight of the US Boeing 747/'Enterprise' combination. Indeed, the facts seem to favour the second possibility put forward by Mr. Porter in the May issue, that 'Kosmolyot' would be a vehicle for a 6-7 ton payload.

How the spacecraft was carried aloft the Tu-95 could also give us further clues to its size. If carried on the back of the aeroplane the 'Kosmolyot' would be a reasonably large vehicle, perhaps with a length similar to a 'Salyut' space station. Mr. Porter suggested that the smaller shuttle might be launched by a Proton-sized booster, and it is notable that 'Salyut' is launched by the Proton rocket.

MICHAEL TAYLOR,
Kelsall, Cheshire, England.

REFERENCE

1. Jane's All the World's Aircraft, 1973-74.

'Clarke Orbit?'

Sir, Geoffrey Hugh Lindop (*Spaceflight*, February 1978, p. 79) has suggested honouring Arthur C. Clarke in the naming of certain Martian surface features. I support Mr. Lindop's suggestion, and would like to add one of my own.

It was Arthur C. Clarke who first pointed out the utility of the 24-hour equatorial orbit for communications satellites. This orbit, now universally accepted as the only logical orbit for most such satellites, is currently referred to as "geo-synchronous" orbit. Both these terms are clumsy, and the former is ambiguous as well. I suggest that it is convenient and very appropriate to call this orbit (and its analogues around other planets) "Clarke orbit."

A principal objection to this usage is that it is non-standard. To this objection, I can only reply that all eventually-standard usages have to start somehow; if the BIS will not start this one, who will?

HENRY SPENCER,
Toronto, Ontario, Canada.

NEXT MONTH – COMBINED ISSUE

The September-October issue of *Spaceflight*, to be published on 25 August, will be a combined issue examining many significant features of contemporary space technology. An eight-page Educational Supplement looks into the development of the NASA Space Telescope. This 10-ton, unmanned, 2.4 metre optical telescope now under development by the Marshall Space Flight Center will be launched into Earth orbit by the Space Shuttle in 1983. There, unhampered by the blurring effects of our atmosphere, it will view celestial objects with resolving powers 10 times greater than the finest ground-based instrument. In the same issue Kenneth Gatland examines reports of a Soviet space shuttle and the Kettering Group give their conclusions on the 'mystery' satellite Cosmos 929. Other articles in the Special Issue include "Making Clouds in Spacelab" by Christine Duncan; "The debate on SETI in the Soviet Union," by Boris Belitsky, and "The psychology of CETI Communications" by Anthony T. Lawton and Penny Wright.

OBITUARIES

We much regret to record the death of George Belyavin, Professor of Microbiology, University College Medical School. Professor Belyavin, a Fellow of the Society for many years, not only Chaired many of the meetings in the 1976/7 "Planets and Life" series of lectures but also edited its Proceedings, which were published in the April 1978 issue of *JBIS*.

We much regret to record the death of Frank Robert Forbes-Taylor (Fellow) at the age of 69 years.

Frank Forbes-Taylor joined the Society in 1952 and was elected Vice-Chairman of the then Bristol Group shortly afterwards. He was subsequently re-elected to this post when the Bristol Group was adopted by the Society and re-named the Western Branch, becoming Branch President at its tenth anniversary in 1962. He played a major part in Branch activities, including the design-study for a Venusian probe published in *JBIS* in 1957.

Practically all of the Western Branch Committee meetings, since 1952, were held in his home in Clifton, Bristol.

* * * * *

Sir, Our son André passed away last year.

We are forwarding the enclosed remittance to cover the cost of the unpaid magazines supplied to date and as a contribution to the BIS Development Fund Appeal, in his memory and in recognition of his keen interest in space technology and exploration.

MR & MRS. SAUMUR
Ottawa, Ontario, Canada.

The Council extend their sincere condolences to Mr & Mrs Saumur on the loss of their son, who was only 20 years of age.

The cheque for $1,000 (£520) which they have presented to the Development Appeal will be allocated to the purchase of some specific item which will bear a plaque in his Memory.

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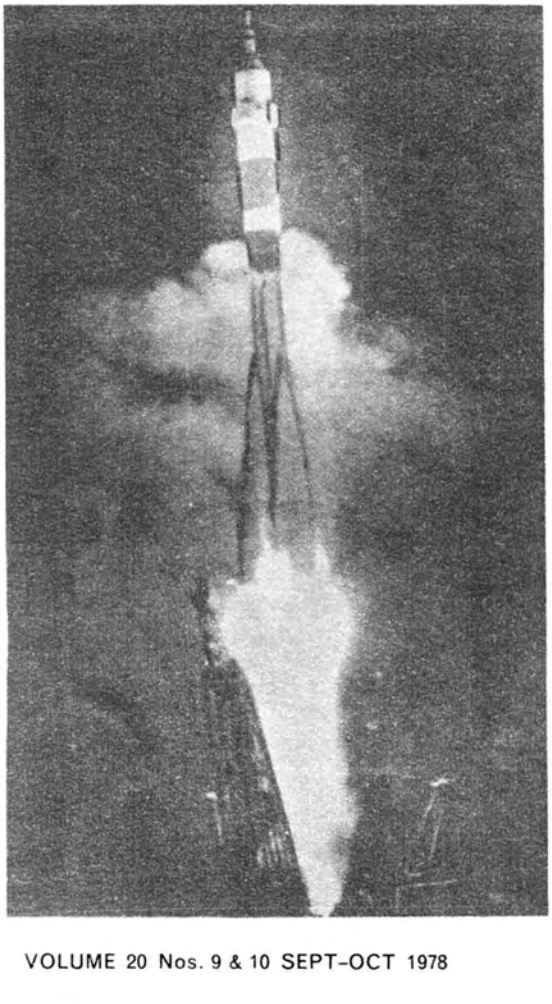
SPACEFLIGHT

88905 Космические полеты № T-9-10
(спейофлайт)
По подписке 1978 г.



VOLUME 20 Nos. 9 & 10 SEPT-OCT 1978

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The British Interplanetary Society

PROJECT DAEDALUS

– A GREAT SUCCESS –

Major interest has developed over the Project Daedalus Report published by the Society in May and which incorporated the results of over ten thousand man-hours of work by the members who made up the study group of professional scientists and engineers.

Overseas publicity has still to filter through, but already the Report has proved a great success. Over two thousand copies have been sold. By scientific standards this is excellent. Initial publicity featured a large-scale writeup in the *Daily Telegraph*, a half-page article headed "British Spacemen: short on rockets, long on ideas" in the *Christian Science Monitor*, and a special BBC TV feature devoted solely to Daedalus, accompanied by nearly three pages in the *Radio Times* – which included a full-page colour photograph of Alan Bond, one of the Editors.

We hope that every member able to do so will try to publicise the Report still further, and thus help to stimulate further contributions to this most absorbing work.

The Report, which runs to 192 pages in large format (8" x 11"), with many line drawings and illustrations, describes an unmanned flyby of Barnard's Star at a distance of six light years from the Sun. It is the most ambitious study yet undertaken for an interstellar starship.

All aspects of the mission are covered, from an assessment of nearby stellar systems, ranking of missions, status of planetary observations and consideration of the stellar properties of the target, to detailed feasibility studies of the propulsion system, auxiliary power sources, propellant acquisition techniques, vehicle materials and structure, besides the payload, reliability and repair problems, navigation, computing facilities and communications.

Copies of the Report, priced at £6 ($ 12.00) post free are available from The Executive Secretary, The British Interplanetary Society, 12, Bessborough Gardens, London, SW1V 2JJ.

BIS DEVELOPMENT PROGRAMME

PROGRESS REPORT NO. 5

THE SOCIETY'S NEW HEADQUARTERS

With building work really getting under way, one's first impression on looking at our new offices is that it is hard to imagine anything less likely to become our new Headquarters Building.

Since last month, down have come the ceilings along with faulty plaster on the walls and several tons of other rubbish. Since work began, about 30 skips have been carted away, with another 20 loads waiting on the site.

Much of the work actually carried out had no immediate visible result. For example, a 14′ deep hole had to be dug, from the bottom of which was excavated a 17′ long horizontal tunnel, to connect up new sewers for the members' loos, the whole cavity then being back-filled with concrete. Special valves had to be fitted owing to proximity to the river and the possibility of flooding. This was difficult and dangerous work.

An examination of some of the old wood showed evidence of woodworm, so a decision was taken to remove all that was visible – even that which formerly interlined concrete floors, to enable a complete renewal to be made.

On the non-destructive side, a start was made on building the internal partitions which will create the new Lecture Room and intended Library area. These are being made by reducing the size of the office space. The new rooms thus provided for members will be approximately 28 ft x 20 ft, i.e. giving a total floor area of 560 sq. ft which, after making provision for a gangway, Chairman's table and projection area – will still be sufficient for an audience of about 60 people, and suitable for many types of Society meetings, excluding film shows and similar events of course, which attract high attendances.

Current proposals involve putting the Lecture Room to quite extensive use with a number of meetings planned to be held during the day. Additionally, in the slightly longer term, it is hoped to "double up" the Lecture Room as an area where the despatch of magazines can be undertaken by the Society itself. This should go a long way towards providing a speedier and more reliable despatch service to members. It would also enable us to do many things on the despatch side which are currently prone to disaster because of the human factor! These proposals are dependent on a sufficient level of income to cover the cost of necessary staffing but would clearly benefit all members, not only those in the UK but those abroad. It will also avoid problems where e.g. members advise Unwins (our Printers) or Burograf (our dispatch agents) of changes to their address – in the mistaken belief that they are thus notifying the Society. Addressing records are kept by the Society alone, so changes notified other than to HQ almost invariably appear to vanish without trace.

(An area of vacant land lies immediately adjacent to the Lecture Room which, if funds and Planning Permission were available, might lend itself to making this still larger, but this remains academic while present and future planned activities absorb so much of the available funds).

Another positive step was the completion of both new roofs and the start made on giving No. 27 a brand new "face lift." This will be completed during the summer months, with the link between the two buildings constructed at the same time.

With the arrival of the long summer months, we are now looking forward to the transformation of our building (in outward appearance at least!) into a more respectable looking edifice!

Additional work emerged as all the things were carried out, as is inevitable when one leaves the planning stage and enters the real hard work world of bricks and mortar, because, as work progresses, old work is exposed and extra work appears which has to be done.

SPACEFLIGHT

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Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

COVER

MEN OF SALYUT. The main problem for cosmonauts today is learning to live and work in outer space, says leading Soviet spaceship designer/cosmonaut Konstantin Feoktistov. "We aim gradually to increase the duration of our space flights. We also have an extensive series of international flights of shorter duration." *Top left,* Soyuz 30 cosmonauts, Russia's Pyotr Klimuk *(right)* and Poland's Miroslaw Hermaszewski who boarded Salyut 6 on 28 June and returned 5 July. *Below,* Soyuz 29 cosmonauts Vladimir Kovalyonok *(left)* and Alexander Ivanchenkov who began their endurance flight aboard Salyut 6 on 17 June. *Right,* launch of Soyuz 29.

Novosti Press Agency

MILESTONES

June

9 Boeing Aerospace Company awards Defense & Space System's Group of TRW $6,768,000 contract to "analyse, design, fabricate, qualify and deliver power amplifiers and transponders through which Inertial Upper Stage (IUS) will communicate with Department of Defense and NASA data relay satellites and data networks." Under separate contract valued at $4,225,000, TRW will design, code, test and deliver software for use with IUS vehicles.

11 Soviets adjust orbit of Salyut 6 to 340 x 356 km x 51.62 inclination in readiness for launch of Soyuz 29.

14 USAF reconnaissance satellite launched from Vandenberg Air Force Base, California, by Titan 3D into 279 x 504 km x 96.8 degrees; period 92.35 min; believed second in series.

15 Third static test is made of Space Shuttle's three main engines installed in an Orbiter aft fuselage section at National Space Technology's Laboratories near Bay St. Louis, Miss. Engines were fired for nearly 40 seconds reaching 90 per cent of rated thrust. (LO_2 and LH_2 are fed to the engines from a flight-type External Tank). Originally planned to last 15 seconds, test duration was extended because of success of two previous firings.

15 Soviets launch Soyuz 29 from Tyuratam at 23.17 hrs (Moscow time) with cosmonauts Colonel Vladimir Kovalyonok (commander) and Alexander Ivanchenkov (civilian flight engineer). Shortly after launch, an orbital correction placed craft into 270 x 314 km x 51.6 deg orbit before beginning docking manoeuvres with Salyut 6. (Kovalyonok made his first space flight in October 1977 as commander of Soyuz 25 in the first successful attempt to dock with Salyut 6. Ivanchenkov, making his first space flight, trained as flight engineer for joint Apollo-Soyuz Test Project (ASTP) in 1975. Ed.).

16 NASA launches third Geostationary Operational Environment Satellite GOES 3 by Delta 2914 from Kennedy Space Center.

17 Soyuz 29 docks with Salyut 6 on the transfer compartment at 00.58 (Moscow time). Cosmonauts will continue research programme begun by the crews of Soyuz 26, 27 and 28. Main studies are: 1. Earth's surface and atmosphere to obtain data of scientific and economic interest; 2. astrophysical experiments and investigations; 3. technological experiments directed at obtaining new materials; 4. bio-medical studies; 5. technical experiments and tests on the structure of the space station and on-board systems and instrumentation. Orbit of Soyuz 29/Salyut 6 combination is 338 x 368 km x 51.6 degrees; period 90.4 min.

20 ESA awards Fr 19 million (£2.2 million) contract to Aérospatiale for development of Systême de Lancement Double Ariane (SYLDA), allowing two satellites to travel in tandem within payload shroud of Ariane launcher.

[Continued on page 339

Owing to the trade agreement giving employees of the printing industry four weeks annual holiday, this is a combined issue covering the months of September and October. The November issue of *Spaceflight* will be published during the fourth week of October, as usual.

В журнале не печатается ряд страниц.

WHERE ARE THEY NOW?

By David J. Shayler

Continued from July issue]

PART TWO

Group 3. Pilot Astronauts. 14 selected 18 October 1963.
Volunteer applications were requested in June 1963 to form a third group of astronauts. This time the requirement of an experienced test pilot was dropped and consequently NASA received far more applications than before. A total of 271 applications were received, 200 from civilians and only 71 from military personnel. Following the usual interviews, tests and examinations, 14 applicants were selected for astronaut training.

The Astronauts:

ALDRIN, Jr. Edwin E. Colonel, USAF (Ret.). Born 20 January 1930, Montclair, New Jersey. Divorced, three children, subsequently remarried. Applied for Group 2, turned down due to lack of test pilot experience. Backup Pilot Gemini 10, reassigned replacement backup Pilot Gemini 9; Pilot Gemini 12 11-14 November 1966, set new EVA record – 5½ hours; backup LMP, then backup CMP of what eventually became Apollo 8; LMP Apollo 11; was second man to walk on the Moon. Worked on Skylab and Shuttle programmes for a short while before retiring from NASA in July 1971 to be come Commandant, Aerospace Research Pilot's School, Edwards Air Force Base, California. Retired USAF 1 March 1972, to enter private buiness and form Research and Engineering Consultants, Los Angeles, California, of which he is currently President.

ANDERS, William A. Colonel, USAF (Ret.). Born 19 October 1933, Hong Kong, China. Married, six children; backup Pilot Gemini 11; Prime LMP third manned Apollo, reassigned to Prime LMP Apollo 8 21-27 December 1968. One of the first three men to orbit the Moon ;backup Command Module Pilot Apollo 11. Resigned NASA and USAF, September 1969, to become Executive Secretary, National Aeronautics and Space Council until 1973 when he joined the Atomic Energy Commission, and with its reorganisation in 1974, became Chairman of the Nuclear Regulatory Commission. In the spring of 1976 he became US Ambassador to Norway. From 1 October 1977, General Manager, Nuclear Energy Product Division, General Electric Nuclear Operations, San Jose, California, a position he still holds.

BASSETT II, Charles A. Major USAF (Deceased). Born 30 December 1931, Dayton, Ohio. Married, two children. Named Pilot Gemini 9, and was in training for a spacewalking experiment when he was killed in the crash of the T-38 jet, in which he was flying, near St. Louis on 28 February 1966.

BEAN, Alan L. Captain, USN (Ret.). Born 15 March 1932, Wheeler, Texas. Divorced, January 1977, two children. Backup Command Pilot Gemini 10; replacement LMP for what eventually became Apollo 9; LMP Apollo 12,14-24 November 1969; fourth man to walk on the Moon; named member Skylab prime crews, January 1972; served as Commander Skylab 3, 28 July-25 September 1973 set new endurance record of over 59 days; backup Commander ASTP Apollo 18. Subsequently assigned to Space Shuttle development, as Head of the Operations and Training Support Group in the Astronaut Office, JSC.

CERNAN, Eugene A. Captain USN (Ret.). Born 14 March 1934, Chicago, Illinois. Married, one child; backup Pilot Gemini 9; reassigned Prime Pilot Gemini 9 upon deaths of original prime crew, 3-6 June 1966; second American to walk in space; backup Pilot Gemini 12; backup LMP Apollo 7; LMP Apollo 10, 18-26 May 1969, and flew LM to within 9 miles of the lunar surface. Backup Commander Apollo 14; Commander Apollo 17 6-19 December 1972, sixth and final Apollo lunar mission, 11th man to walk on the Moon, last man of Apollo to leave his footprints on the lunar surface. From September 1973 Special Assistant to the Manager Apollo Spacecraft Programme at JSC, serving in this capacity as Deputy Director ASTP, until his departure from NASA and the USN on 1 July 1976. Currently Executive Vice President, International Coral Petroleum Company, Houston, Texas.

CHAFFEE, Roger B. Lt.Cdr. USN (Deceased). Born 15 February 1935, Grand Rapids, Michigan. Married, two children. Selected for first manned Apollo flight as LMP on 21 March 1966, scheduled then for February 1967; died 27 January 1967, Cape Kennedy, Florida, during simulated countdown of Apollo 1 spacecraft in a flash fire within capsule; buried Arlington Military Cemetary, Washington.

COLLINS, Michael. Major General USAF (Ret.). Born 31 October 1930, Rome, Italy. Married, three children. Backup Pilot Gemini 7; Pilot Gemini 10 18-21 July 1966, third American to walk in space; LMP Apollo 014 mission, and upon the cancellation of that flight became CMP of what eventually became Apollo 8. Removed from flight crew due to necessity to undergo surgery for a spinal complaint; returned to flight status and became CMP Apollo 11, first manned lunar landing mission 16-24 July 1969. Retired from NASA and USAF December 1969 becoming Assistant Secretary of State for Public Affairs in January 1970; since February 1971 has served as Director of the National Air and Space Museum, Smithsonian Institute, Washington, D.C. Had he stayed in the astronaut programme he would probably have become backup Commander Apollo 14, thus making him eligible to command Apollo 17 and walk on the Moon.

CUNNINGHAM, R. Walter. Civilian. Born 16 March 1932, Creston, Iowa. Married, two children. Served as backup LMP on an "early" Apollo flight; backup LMP Apollo 1; LMP Apollo 7 11-22 October 1968; headed Skylab project for a short while, being tipped as likely Commander of the first mission; resigned NASA August 1971 to become Vice President, Century Development, Houston, Texas; subsequently President of Hydro-Tech Development Company, Houston. Currently Senior Vice President/Director of Engineering, 3D International, Houston.

EISELE, Donn F. Colonel USAF (Ret.) Born 23 June 1930, Columbus, Ohio. Divorced, four children, subsequently remarried, one child (by second marriage). CMP of an "early" Apollo; backup CMP of Apollo 1; CMP Apollo 7 11-22 October 1968; backup CMP Apollo 10; eligible to fly Apollo 13 as prime crew member, possibly as LMP with a chance to walk on the Moon; however, he stepped down from flight status and served in 1970-72 as Technical Assistant for Manned Space Flight, NASA Langley Research Center, Hampton, Virginia; retired NASA and USAF July 1972 to become Peace Corps Director in Thailand; he subsequently resigned that post and is currently Eastern Sales Manager for the Marion Power Shovel Company, Inc., which is based in Williamsburg, Virginia.

FREEMAN, Theodore C. Captain USAF (Deceased). Born 18 February 1930, Haverford, Pennsylvania. Married, one

GROUP 3 ASTRONAUTS. *Standing left to right,* Michael Collins; Donn F. Eisele; Richard F. Gordon; David R. Scott; R. Walter Cunningham; Theodore Freeman; Russell L. Schweickart and Clifton C. Williams. *Seated, left to right,* Edwin E. Aldrin; William A. Anders; Charles A. Bassett; Alan L. Bean; Eugene A. Cernan and Roger B. Chaffee.

child. Died 31 October 1964 when his T-38 jet crashed at Ellington Air Force Base, following the collision of the jet with a flock of geese.

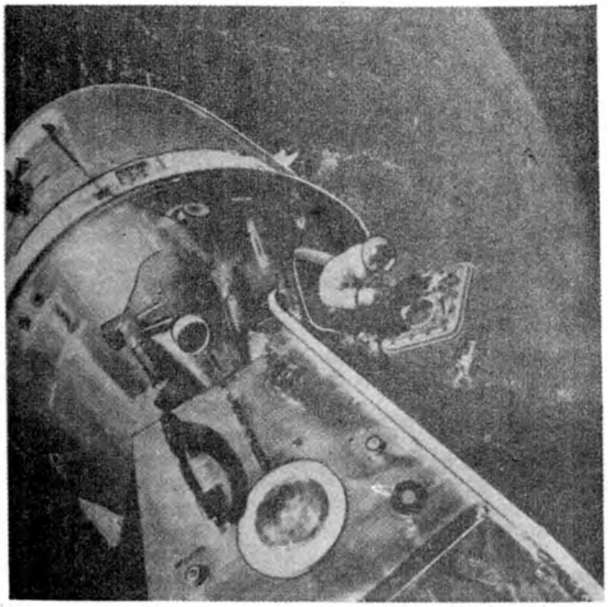
GORDON, Jr. Richard F. Captain USN (Ret.). Born 5 October 1929, Seattle, Washington. Married, six children. Backup pilot Gemini 11 12-15 September 1966; backup CMP Apollo 9; CMP Apollo 12 14-24 November 1969; backup Commander Apollo 15; and had Apollo 18 lunar mission been retained on the launch schedule he would possibly have commanded the mission and walked on the Moon. On 1 January 1972 he retired from both NASA and the USN to become Executive Vice President of the New Orleans Saints of the National Football League, a position he resigned on 1 April 1977 to transfer to a division of the John Mecom Company, Houston,Texas.

SCHWEICKART, Russell L. Civilian. Born 25 October 1935, Neptune, New Jersey. Married, five children. Original LMP for Apollo 1; then LMP for Apollo 205B; LMP for second manned Apollo, reassigned LMP of third manned Apollo which became Apollo 9 3-13 March 1969, first man to spacewalk from an Apollo spacecraft; named member of Skylab astronaut detachment January 1972, serving as backup Commander Skylab 2, first manned mission; responsible for design, development and planning of all Skylab EVA operations, rehearsing every one on the Earth before the astronauts attempted them in space. In May 1974 he left the astronaut office on temporary assignment to NASA Headquarters, Washington, D.C. as NASA's Director of User Affairs in the Office of Applications. Subsequently, assigned Assistant for Payload Operations, Office of Planning and Program Integration, NASA Headquarters in November 1976. Took leave of absence in summer of 1977 to assist Govenor Brown of California in preparations for the State of California's 'Space Week' celebrations; available for Shuttle flights.

SCOTT, David R. Colonel, USAF (Ret.). Born 6 June 1932, San Antonio, Texas. Married, two children. Pilot Gemini 8 16 March 1966; backup senior pilot for Apollo 1 for a short while before being assigned prime CMP for Apollo 8, reassigned CMP for Apollo 9 3-13 March 1969, conducted 1 hour standup EVA from CM hatch. Backup Commander

GROUP 4 ASTRONAUTS
Standing, left to right,
Owen K. Garriott and
Edward G. Gibson.
Seated, left to right,
Frank C. Michel;
Harrison H. Schmitt and
Joseph P. Kerwin.

NASA



APOLLO EVA. Apollo 9 astronaut David Scott is photographed during extravehicular activity by Russell Schweickart from the porch of the Lunar Module. Scott stands in the open hatch of the Command Module. The two vehicles are docked together over the central United States.

National Aeronautics and Space Administration

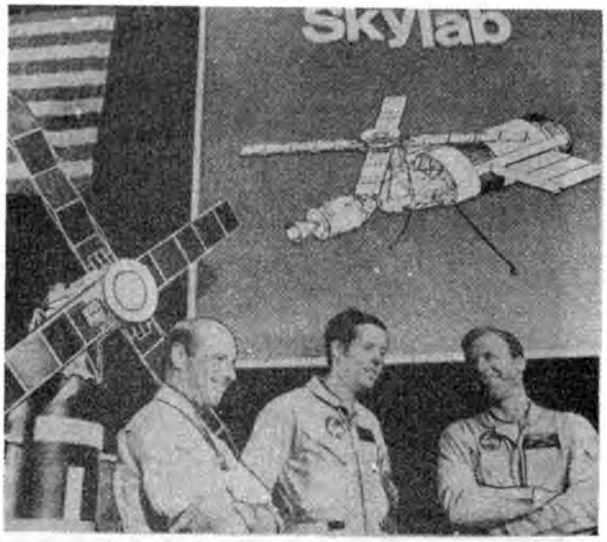
Apollo 12; Commander Apollo 15 26 July-7 August 1971, seventh man to walk on the Moon, first to drive over it; backup Commander Apollo 17 until May 1972. In July 1972 served as Special Assistant for Mission Operations and Government Furnished Equipment in the Apollo Spacecraft Office, primarily as Special Assistant, Mission Operations, ASTP. August 1973-April 1975 served as Deputy Director, NASA Dryden Flight Research Center, Edwards, California; since April 1975 has served as Director of that Center.

WILLIAMS, Jr. Clifton C. Major, USMC (Deceased). Born 26 September 1932, Mobile, Alabama. Married, one child. Backup Pilot Gemini 10; died 5 October 1967 in the crash of his T-38 jet near Tallahassee, Florida. Had he lived he would have served on Pete Conrad's Apollo crew serving as backup LMP Apollo 9 and LMP Apollo 12 becoming the fourth man to walk on the Moon; he was replaced in both positions by his Gemini 10 backup Commander Alan Bean.

Group 4. Scientist Astronauts. 6 selected 28 June 1965.
October 1964, NASA calls for applications for the selection of a group of scientist astronauts for the forthcoming Apollo lunar missions. By January 1965 a total of 1,492 letters of interest had been received. Of these a total of 422 were selected from people having the required qualifications; joint evaluation by NASA and the National Academy of Sciences reduced this number to 16. Following extensive physical examinations six from the group were selected as astronaut trainees.

The Astronauts

GARRIOTT, Owen K. Civilian, Dr. (Ph.D. Electrical Engineering). Born 22 November 1930, Enid, Oklahoma. Married, four children. Support crew Apollo 12; Science Pilot Skylab 3 second manned mission 28 July-25 September 1973, during which he conducted three separate EVA's outside the Skylab station; May-September 1974 Chief Scientist Astronauts JSC; subsequently went on sabbatical leave at Stanford University, returning to JSC in the fall of 1976; became Director Science and Applications Directorate, JSC; currently Assistant Director for Science in the Astronaut Office, JSC.



FIRST SKYLAB TEAM. Crewmen for the first Skylab mission brief newsmen at the Manned Spacecraft Center near Houston, Texas. *Left to right*; Charles Conrad, commander; Joseph Kerwin, science pilot, and Paul Weitz, pilot. Kerwin was part of the Group 4 selection of June 1965.

National Aeronautics and Space Administration

GIBSON, Edward G. Civilian, Dr. (Ph.D. Engineering and Physics). Born 8 November 1936, Buffalo, New York. Married, four children. Support crew member Apollo 12; Science Pilot Skylab 4 16 November 1973-9 February 1974, set new space endurance record of just over 84 days. Resigned from NASA on 1 December 1974 to join Aerospace Corporation, El Segundo, California, specialising in interpretation of solar data gathered by Skylab; he then became senior consultant for Spacelab operations at VFW Fokker/ ERNO, Bremen, West Germany, in 1976. On 7 March 1977 Gibson rejoined the Astronaut Office JSC and was assigned to the Mission Specialist Office, Space Shuttle Development.

GRAVELINE,Duane E. Civilian, Dr. (Ph.D. Medicine). Born 2 March 1931, New Port, Vermont. Married, five children. Resigned for personal reasons in August 1965 to take up a post with the State of Vermont Department of Health; he subsequently resigned that position and currently is set up in his own practise, the Health Maintenance Center, Colchester, Vermont.

KERWIN. Joseph P. Captain USN, M.D. (Medicine). Born 19 February 1932, Oakpark, Illinois. Married, three children. Member of three man crew assigned to the thermal vacuum testing of prototype CM (Apollo Training Vehicle 2TV-1) in 1968; Science Pilot Skylab 2, first manned flight 25 May-22 June 1973; participated in NASA's 'Outlook for Space' study; September 1974 became Chief Scientist Astronauts; subsequently assigned to Shuttle work and became Chief of the Life Sciences Astronaut Office; currently Head of Mission Specialist Group. Astronaut Office, Space Shuttle Programme, JSC.

MICHEL, Frank C. Civilian. Dr. (Ph.D Physics). Born 5 June 1934, La Crosse, Wisconsin. Married,two children. Resigned from NASA in August 1969 to become Professor of Physics at Rice University, Houston, Texas; currently Chairman of the Space Physics and Astronomy Program there.

SCHMITT, Harrison H. Civilian, Dr. (Ph.D. Geology). Born 3 July 1935, Santa Rita, New Mexico. Unmarried. Participated in the geological training of Apollo astronauts for lunar landing missions and in investigations of returned lunar samples. Backup LMP Apollo 15; original prime LMP Apollo 18, reassigned LMP Apollo 17 6-19 December 1972, 12th and last man of Apollo to step onto the lunar surface. Chief of Scientist Astronauts until February 1974, when appointed Special Assistant to NASA Administrator for Energy Research and Development; appointed NASA Assistant Administrator for Energy Programmes, NASA Headquarters, Washington, D. C. in May 1974. Resigned from NASA on 30 August 1975 to enter politics. He now resides in Albuquerque, New Mexico, and was elected Senator (Republican) for State of New Mexico 2 November 1976.

[To be continued

PIONEER DETECTS GAMMA "BURST"

Scientists have now confirmed that Pioneer Venus 1, on the first leg of its seven-month voyage to orbit around Venus, detected an extremely powerful "burst" of gamma rays from "somewhere in the Universe."

So-called gamma ray bursts, unknown until 1973, have enormous energies and occur about once per month, seemingly from random points in our Galaxy or even beyond. Discovering their origin—"black holes", brilliant supernovae, neutron stars or some totally unexpected source—represents one of astronomy's most difficult tasks. Over the course of its 482 million km (300 million miles) mission, Pioneer Venus' measurements of these puzzling bursts should enable scientists for the first time to accurately track down their origins.

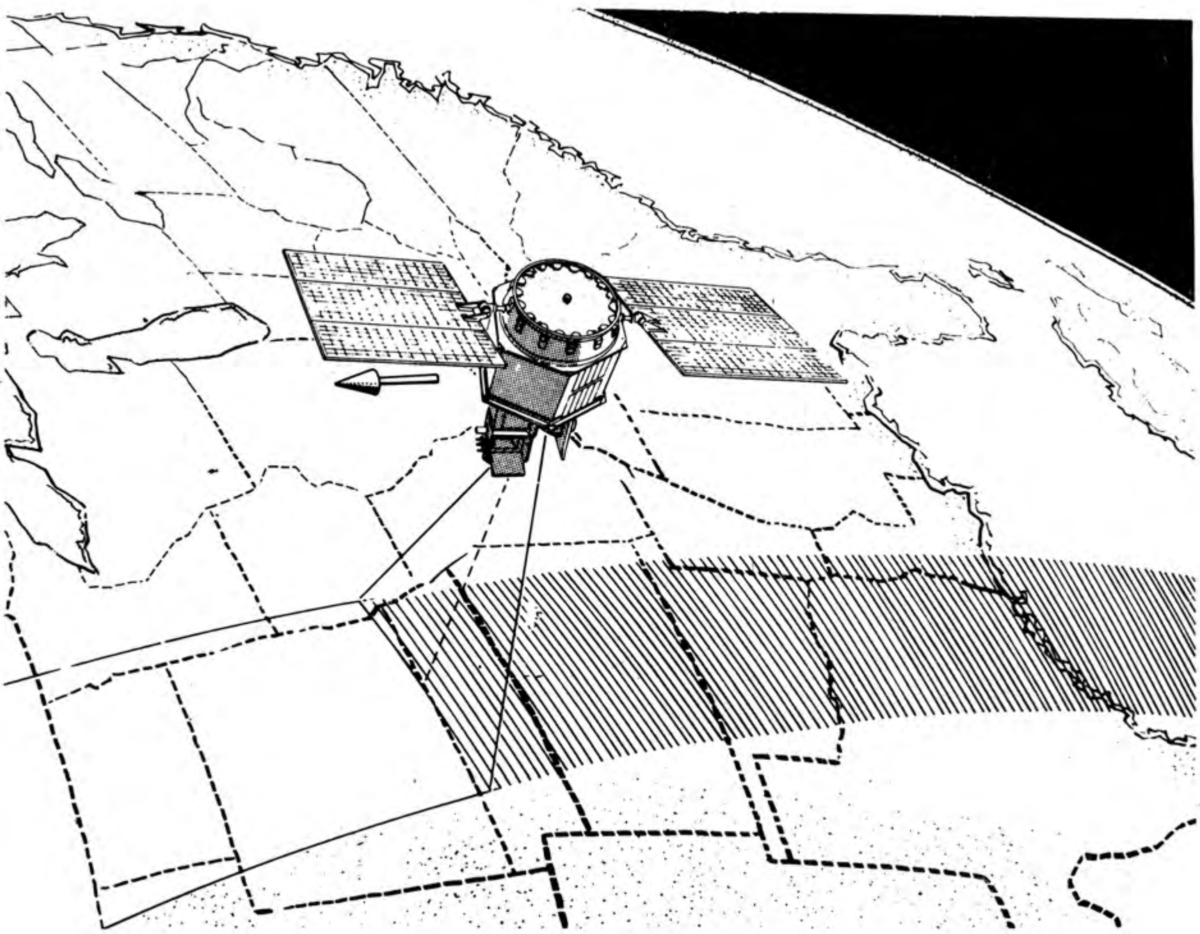
Designed to orbit Venus to study its weather processes, the Pioneer Venus Orbiter spacecraft (Pioneer Venus 1) carries six interplanetary instruments, including a 2.8 kg (6.4 lb) gamma ray burst detector. The instrument's twin sodium iodide detectors sensed a "classical" two second pulse of these very high energy photons just 33 hours after lift-off and 585,000 km (351,000 miles) from Earth.

Two other American spacecraft also detected the gamma ray blast—VELA, a Department of Energy satellite circling the Earth and HELIOS 2, a NASA-European scientific satellite orbiting the Sun. Scientists will correlate the observations of the Venus Orbiter with these satellites' data to obtain a rough "fix" on the burst. As Pioneer Venus 1 speeds toward Venus, away from Earth satellites, such "triangulation" techniques will pinpoint the origin of gamma ray bursts with ever-increasing accuracy.

Ideally, measurements of the gamma ray sources will be made with an accuracy of less than one minute of arc, precise enough for an attempt at identifying the source with powerful optical or radio telescopes on Earth. By locating the origin of the bursts (probably within our own galaxy), scientists hope to deduce what extraordinary physical events produce these enormously high energy explosions. None of the theories proposed in the past few years satisfactorily accounts for the gamma ray bursts.

One popular theory suggests the existence of binary star systems involving a star like the Sun and an extremely dense entity such as a "black hole", so termed because not even light can escape its incredibly strong gravity field. "Bursts" occur when chunks of stellar material flowing from the star fall into the black hole. This event ignites thermonuclear explosions much like hydrogen bomb blasts and gives off high energy gamma rays which streak across the Universe at the speed of light. The leading candidate for such a system is Cygnus X-1 in our Galaxy.

A SATELLITE THAT TAKES THE EARTH'S TEMPERATURE



The first spacecraft built to test the feasibility of measuring variations in the Earth's temperature was launched from the Western Test Range, California, by a Scout rocket on 25 April 1978. Called the Heat Capacity Mapping Mission (HCMM), this experimental satellite travels in a circular, Sun-synchronous 620-km (385 mile) orbit that allows for measuring mid-latitude test areas of the Earth's surface for their minimum temperatures and then measuring those same areas' maximum temperatures about 11 hours later.

A two-channel scanning radiometer acquires images in the visible and near infrared spectrum during the day and in the thermal infrared spectrum both day and night. Resolution of the two channels is about 0.5 by 0.5 km (1,800 ft.) as the spacecraft acquires data along a 700-km (435 miles) wide swath.

HCMM is the first of a series of low-cost, modular-design spacecraft built for the Applications Explorer Missions (AEM) – small experimental craft in special orbits to satisfy unique experimental requirements. This particular mission was designed to allow scientists to determine the feasibility of using day-night thermal infrared remote sensor-derived data for:

- Discrimination of various rock types and possibly locating mineral resources.
- Measuring and monitoring surface soil moisture changes.
- Measuring plant canopy temperatures at frequent intervals to determine transpiration of water and plant stress.
- Measuring urban heat islands.
- Mapping surface temperature changes on land and water bodies.
- Deriving information from snow fields for water runoff prediction.

HCMM data is being correlated with that received from other satellites, especially from Landsat, the Earth resources spacecraft, and with ground observations, to provide a better insight into detecting temporal temperature variations of the Earth's surface.

Temperature Variation of Surface Rocks

The spacecraft is unique in that its day-night heat measurement sequence permits readings of temperature changes associated with solar heating during the daytime and radiative cooling at night. This temperature difference is re-

lated to the properties of the surface layer approximately 5-10 cm (2-4 in.) deep being measured. For instance, some types of rocks such as shale have a wide day-night temperature difference, while other types of rock such as quartz have a smaller day-night temperature difference.

Test sites for HCMM measurements are located in various parts of the Continental United States, Western Europe and Australia. Twelve American and 12 foreign investigators are participating in the programme.

Some of the experiments are to:

- Discriminate among rock types and identify such features as subsurface faults or fracture not seen in the visible spectrum. For instance, some types of rock formations may emit similar radiation characteristics in the visible spectrum due to weathering erosion, or silt cover, whereas the thermal spectral band, by measuring temperature differences, may indicate structural and compositional differences.

- Survey soil moisture of cultivated areas including some with extensive irrigation. For example, wet soils have a very low temperature variation during the day-night period, while dry soils and sand reach very high temperatures during the day and become quite cold at night.

- Determine whether plants are "running temperatures" by observing the changes in temperature readings of the vegetated areas. When a plant has adequate water, its use of that water – transpiration – keeps it cooler than the surrounding air. A dehydrated plant exhibits a higher temperature, thus indicating plant stress.

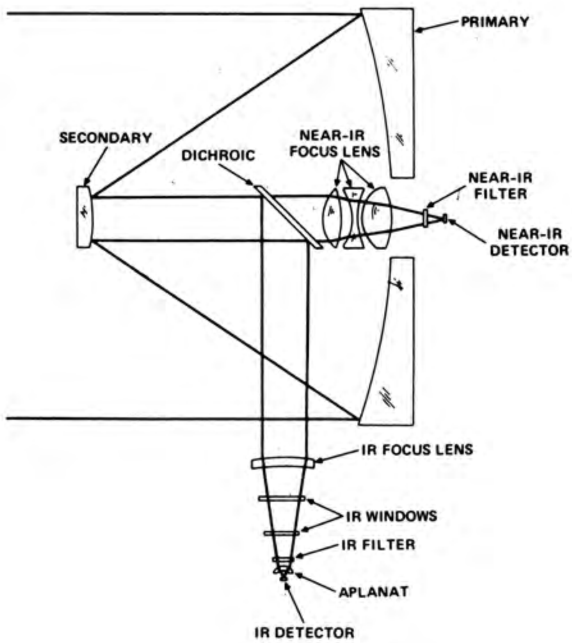
- Map flood runoff and thermal effluents into coastal zones and the Great Lakes by measuring water temperature differences. Such data are expected to improve the monitoring from space of environmental and ecological disturbances to fresh and tidal water resources, i.e., animal, fish and plant life.

- Study "heat islands" – concentrations of heat rising from large metropolitan areas. It is known that the higher temperatures associated with heat from cities can affect their local weather, but it is not known whether these higher temperatures can cause long-lasting changes in regional climate.

- Measure snow fields. Many areas of the country depend on melted snow for their water supplies. Other areas are threatened by floods caused by melting snow. Although snow field areas have been monitored for a number of years by Landsat and other satellites, HCMM should add improved temperature measurements to these snowmelt data and assist scientists in calculating the time and rate of snowmelt.

The HCMM is made up of two parts: (1) the instrument, the Heat Capacity Mapping Radiometer (HCMR) and its unique supporting gear; and (2) the spacecraft base module, or bus, containing the necessary data handling, power supply, communications and command and attitude control subsystems to support the instrument module.

The spacecraft bus is based on a state-of-the-art modular concept that keeps its cost relatively low, about $5 million. Its single hydrazine motor provides the spacecraft with the capability to alter its orbit altitude for experiments requiring special orbits or early engineering evaluation of mission sensors. The bus weighs about 100 kg (220 lb.). Its solar panels provide an orbital average power of 50 watts. A three-axis control of 1 to 2 degrees enables the satellite to keep



Optical diagram for Heat Capacity Mapping Radiometer (HCMR).

pointed toward the Earth.

NASA's Goddard Space Flight Center, Greenbelt, Maryland, is responsible for the design, integration and testing of the satellite and data processing. HCMM data will be collected in real time when the satellite is within reception of the following NASA receiving stations – Merritt Island, Florida; Goldstone, California; Fairbanks, Alaska; Orroral, Australia; Madrid, Spain; and the Goddard Center Engineering Test Center at Greenbelt.

The base module was built by the Boeing Aerospace Company, Seattle, Washington, and the instrument by the International Telephone and Telegraph Company, Fort Wayne, Indiana.

FARNBOROUGH INTERNATIONAL '78

This year's International Aerospace Exhibition and Flying Display at Farnborough in September will be one of the largest ever staged in the United Kingdom. There will be the usual wide range of missile and space exhibits.

Some 418 companies from 17 countries will be represented including 48 companies from the United States, including virtually all the leading aerospace firms. Six overseas countries have requested national stands for their industries with 30 French aerospace firms represented in a joint area, 29 from the Netherlands and other grouped exhibits from Canada (5), West Germany (7), Italy (10) and Switzerland (9). For the first time exhibitors are taking part from Japan (6), the Argentine and Brazil. The Soviet Union has indicated it will be presenting at least one civil aircraft.

Press day for the Show is 3 September with four Trade Days to follow, when admission is by invitation only. The public are admitted for the first time on the Public Premiere, Friday 8 September and the Main public Days are Saturday and Sunday 9 and 10 September.

Further details from The Society of British Aerospace Companies Ltd., 29 King Street, St. James's, London, SW1.

CENTAUR REACHES FIFTY

By Andrew Wilson

Introduction

With the launch of Intelsat 4AE, NASA's high-energy stage Centaur reached its half-century in a distinguished career so far spanning 15 years.

The original requirement for the first LO_2/LH_2 upper stage came from plans to launch Advent, an active comsat into a geostationary orbit. Other objectives were capabilities to put 8,500 lb. (3, 800 kg) into low Earth orbit, or send 2,300 lb. (1.030 kg) to the Moon or 1,300 lb. (590 kg) to the nearer planets [1].

The Advanced Research Projects Agency (ARPA) awarded the contract to Convair Astronautics and Pratt & Whitney (for the engines) in November 1958, demanding a vehicle capable of long coast periods and with restartable engines. The project was handed over to NASA on 1 July 1959, who gave technical direction to Marshall Space Flight Center in 1960.

Before is was shelved, the Advent programme was largely responsible for the final features of the Centaur stage:

Length	28.5 ft. (8.69 m).
Diameter	10 ft. (2.03 m).
Fuelled wt.	32,000 lb. (14,500 kg)
Dry wt.	4,000 lb. (1,800 kg).
Engines	Two P&W RL-10
Thrust	2 x 15,000 lbf. (2 x 67,200N).

Vehicle Description

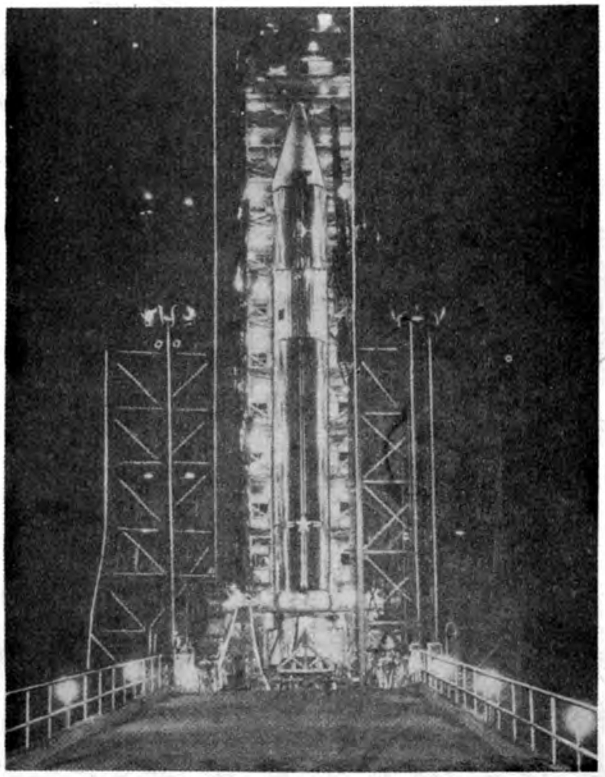
Using the Atlas as booster dictated a Centaur diameter of 10 ft. (3.05 m) while the two stages were separated by a 13 ft. (3.96 m) long interstage constructed of aluminium alloy. The programme saved on costs by largely employing construction techniques used in building the Atlas, e.g., using internal pressure to maintain stage strength. Most of the problems to be overcome arose from using liquid hydrogen as fuel which, although it was efficient with LO_2, was difficult to handle. Insulation was an important factor in preventing fuel loss and during the Centaur coast phases the vehicle was oriented with the engines pointing towards the Sun with the double objective of stopping the hydrogen tank from overheating and keeping the engines warm for the next ignition.

Guidance was taken over from the Atlas by the inertial system of the Centaur, built by the Minneapolis-Honeywell Regulator Company.

Early Flights

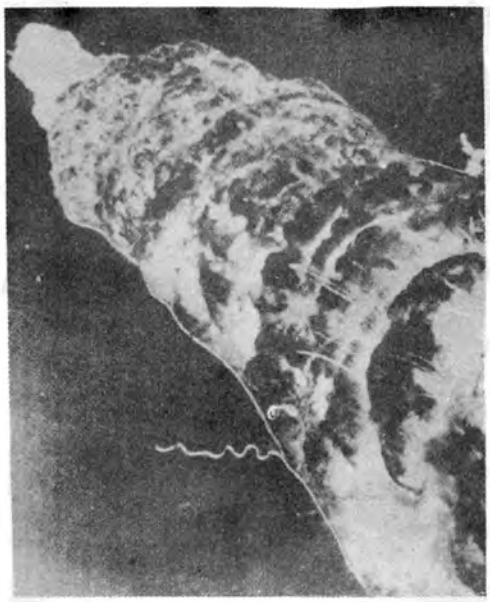
Atlas Centaur 1 (AC-1) was planned to fly 1,175 miles (1,890 km) downrange from LC 36 at Cape Canaveral to demonstrate Centaur behaviour (ignition, guidance and separation) and Atlas-Centaur integrity. The Atlas D first stage was to provide thrust for 4½ minutes, followed by the four insulation panels peeling away from the sides of the Centaur and separation of the nose fairing before the two vehicles parted. The start cycle of the two Centaur engines was to be completed except for actual ignition, followed by vehicle orientation as in an operational mission to prevent excessive fuel evaporation. At T+11m reorientation was to begin, before the engines were fired for 25 seconds to initiate reentry. The splashdown target was the Sargasso Sea.

The flight on 8 May 1962 was going well until T+55s when the vehicle exploded at 20,000 ft. (6,100 m) after the nose fairing structure failed. Tracking camera film clearly showed the Atlas to be burning well while the upper stage was breaking up. The fairing was 18 ft. (5.49 m) high,



The first Atlas-Centaur on Launch Complex 36 at the Atlantic Missile Range, Cape Canaveral, Florida. The vehicle consisted of a modified Atlas intercontinental ballistic missile topped by a Centaur upper stage of similar thin-skin stainless steel construction. *Below,* the launching on 8 May 1962 which ended in a spectacular explosion at an altitude of 6,100 metres.

General Dynamics, Convair Division



weighed 750 lb. (340 kg), split into two sections and was designed to protect the Centaur from temperatures up to 1,200°F (650°C).

Surveyor

Of the following six R&D flights, three failed but then the Surveyor soft lunar landing programme began. The fifth to seventh AC flights (R&D) carried Surveyor Demonstration mass models to prove the vehicle could handle the lunar mission requirements. Interrupted only by the R&D mission of AC-9 in October 1966, the following flights carried Surveyors 1 to 7 in a highly successful series, both for the launch vehicle and for the lunar landers.

The success for Atlas Centaur did not end there. From 1968 to 1971, the combination launched two ATS satellites, an astronomical observatory, two Mars fly-by probes and the first Intelsat 4 comsat.

Mariner H

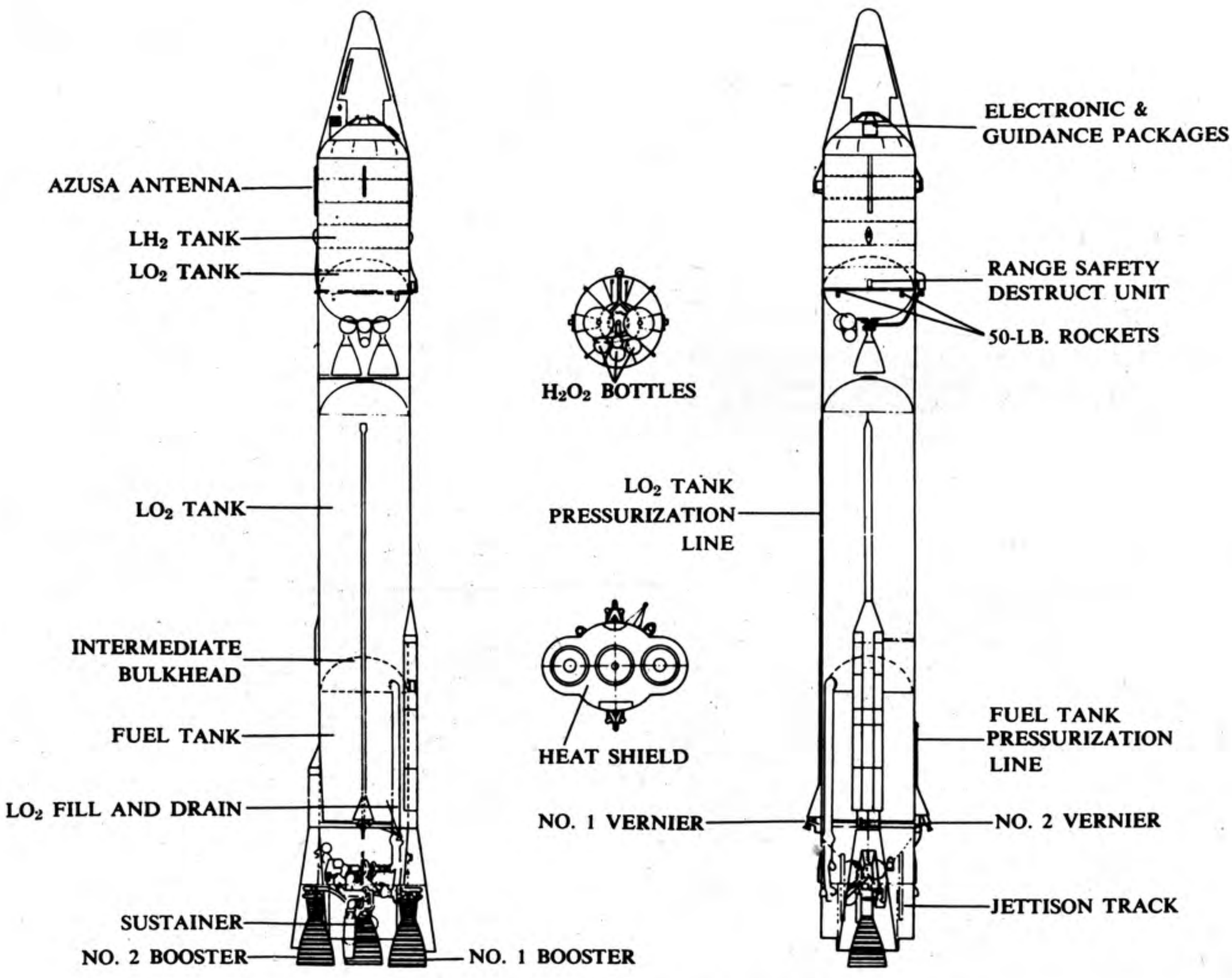
Failure struck on 8 May 1971 with the launch of Mariner H (to have been Mariner 8), the first of a pair of payloads intended to map Mars from orbit. Signals from the rate gyro to the actuators steering the Centaur engines stopped after the engines had burned for about 25 seconds, causing gimballing in pitch to stop at T+4.7 m. As a result, the Centaur and its payload began to tumble, impacting 900 miles (1,450 km) downrange in the Atlantic.

With this failure in mind, the autopilot was tested for the Mariner 9 launch for faulty integrated circuits and given extra thermal and vibration tests. A further problem was noted in the Mariner 9 Centaur, causing the payload to be demated and the launch date to be slipped.

Atlas Change

The first twelve flights (although some carried useful payloads they were essentially engineering missions) used modified Atlas D's, redesignated LV-3C, as first stage. The 13th flight employed the first standardised Atlas intended for the Centaur, the SLV-3C. This was eventually to be used for 17 missions, the last being the launch of OAO 3 in 1972.

When the Centaur D was modified to the D-1A form, the Atlas was simplified by deleting the autopilot, programmer and telemetry units. This was designated the SLV-3D and is the version currently in use.



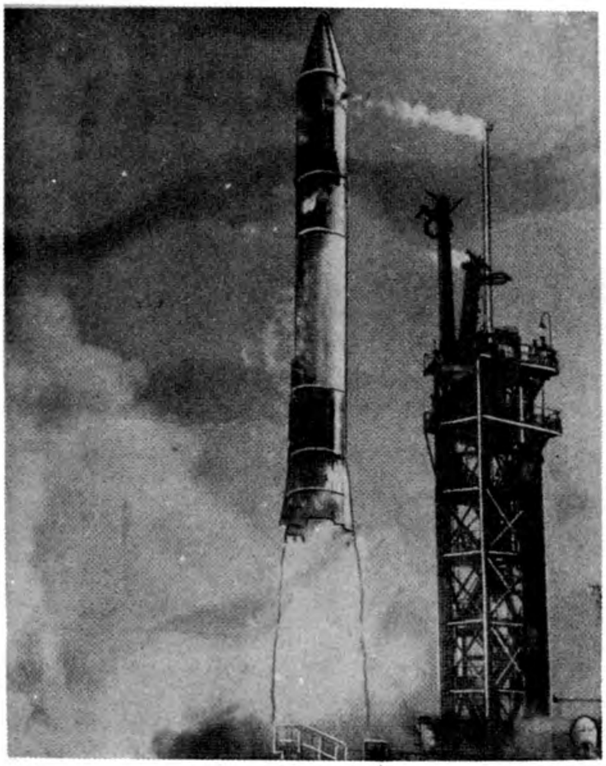
Major Atlas-Centaur systems are shown in three-way view.

Centaur Reaches Fifty/contd.

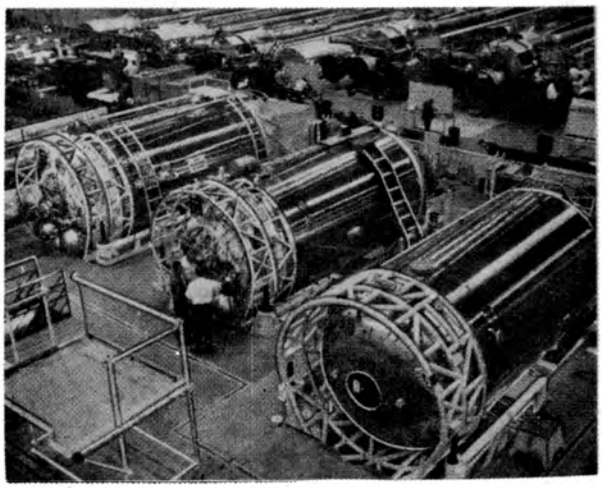
Table 1. Centaur launch list.

Vehicle Sequence Number	Launch Date	Vehicle Number	Atlas Number	Launch Site	Mission
1	8. 5. 62	AC 1	104D	36A	*R&D
2	27.11. 63	AC 2	126D	36A	R&D
3	30. 6. 64	AC 3	135D	36A	*R&D
4	11.12. 64	AC 4	146D	36A	R&D
5	2. 3. 65	AC 5	156D	36A	*R&D + SD-1
6	11. 8. 65	AC 6	151D	36B	*R&D + SD-2
7	7. 4. 66	AC 8	184D	36B	*R&D + SD-3
8	30. 5. 66	AC 10	290D	36A	Surveyor 1
9	20. 9. 66	AC 7	194D	36A	Surveyor 2
10	26.10. 66	AC 9	174D	36B	R&D
11	17. 4. 67	AC 12	292D	36B	Surveyor 3
12	14. 7. 67	AC 11	291D	36A	Surveyor 4
13	8. 9. 67	AC 13	5901C	36B	Surveyor 5
14	7.11. 67	AC 14	5902C	36B	Surveyor 6
15	7. 1. 68	AC 15	5903C	36A	Surveyor 7
16	10. 8. 68	AC 17	5104C	36A	ATS 4
17	7.12. 68	AC 16	5002C	36B	OAO 2
18	24. 2. 69	AC 20	5403C	36B	Mariner 6
19	27. 3. 69	AC 19	5105C	36A	Mariner 7
20	12. 8. 69	AC 18	5402C	36A	ATS 5
21	30.11. 70	AC 21	5003C	36B	*OAO B
22	25. 1. 71	AC 25	5005C	36A	Intelsat 4A
23	8. 5. 71	AC 24	5405C	36A	*Mariner H
24	30. 5. 71	AC 25	5404C	36B	Mariner 9
25	19.12. 71	AC 26	5006C	36A	Intelsat 4B
26	22. 1. 72	AC 28	5008C	36B	Intelsat 4C
27	2. 3. 72	AC 27	5007C	36A	Pioneer 10
28	13. 6. 72	AC 29	5009C	36B	Intelsat 4D
29	21. 8. 72	AC 22	5004C	36B	OAÔ 3
30	5. 4. 73	AC 30	5011C	36B	Pioneer 11
31	23. 8. 73	AC 31	5010D	36A	Intelsat 4E
32	3.11. 73	AC 34	5014D	36B	Mariner 10
33	11. 2. 74	TC 1	n.a.	41	*test
34	21.11. 74	AC 32	5012D	36B	Intelsat 4F
35	10.12. 74	TC 2	n.a.	41	Helios 1
36	20. 2. 75	AC 33	5015D	36A	*Intelsat 4G
37	22. 5. 75	AC 35	5018D	36A	Intelsat 4H
38	20. 8. 75	TC 4	n.a.	41	Viking 1
39	9. 9. 75	TC 3	n.a.	41	Viking 2
40	25. 9. 75	AC 36	5016D	36B	Intelsat 4AA
41	15. 1. 76	TC 5	n.a.	41	Helios 2
42	29. 1. 76	AC 37	5017D	36B	Intelsat 4AB
43	13. 5. 76	AC 38	5020D	36A	Comstar 1
44	22. 7. 76	AC 40	5022D	36B	Comstar 2
45	26. 5. 77	AC 39	5019D	36A	Intelsat 4AC
46	12. 8. 77	AC 45	5025D	36B	HEAO 1
47	29. 8. 77	TC 7	n.a.	41	Voyager 2
48	5. 9. 77	TC 6	n.a.	41	Voyager 1
49	29. 9. 77	AC 43	5701D	36A	*Intelsat 4AD
50	6. 1. 78				Intelsat 4AE

*All launches from ETR. n.a. : not applicable. S.D. : Surveyor Demonstration. * : unsuccessful.*



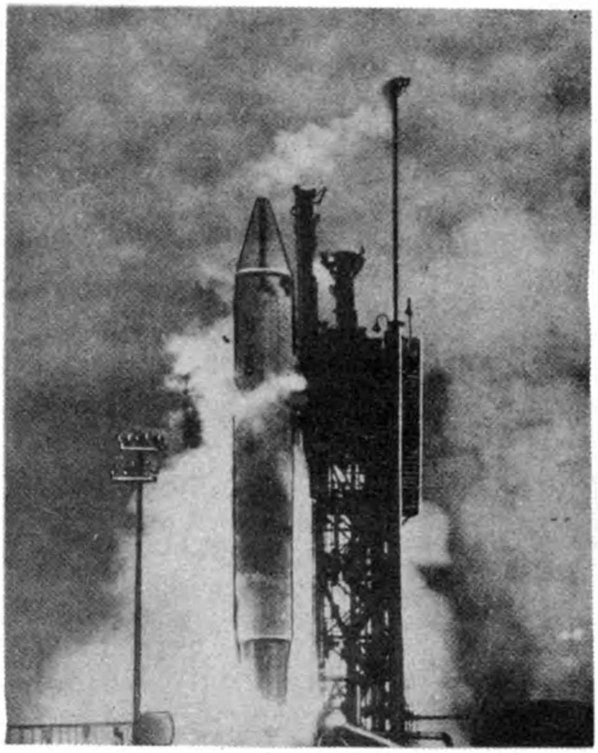
Launch of AC-4 on an R & D flight 11 December 1964. The black bands on the nose cover separation lines of the fairing.



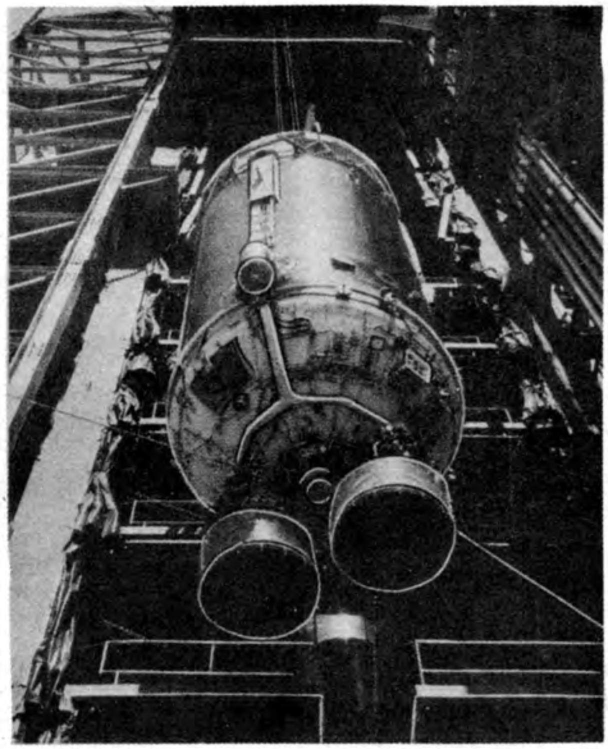
Three Centaur stages under construction at the Convair plant in California, with Atlas frames in the background. The Centaur on the right has still to receive its wiring and electronic packages.

Left: **Early Atlas-Centaur vehicle; general arrangement of engines, tanks, guidance packages and range safety destruct unit.**

All Illustrations General Dynamics, Convair Division



Collapse of AC-5 on pad 36A after the Atlas engines shut down early on 2 March 1965. The Centaur supported a mass demonstration model of the Surveyor spacecraft.



The Centaur upper stage being hoisted up to mate with its Atlas booster on pad 36 at Cape Canaveral.

Third Stage

A third stage was added to the AC combination in the form of the TE-M-364-4 solid fuel motor for launching the two Pioneer spacecraft to Jupiter in 1972 and 1973.

Other Failures

At the end of 1970, OAO-B failed to orbit when the 2,400 lb. (1.090 kg) nose fairing failed to separate.

The next vehicle failure was during the launch of Intelsat G in 1975, but this time the Atlas booster was responsible because of problems during separation of the two outboard boosters. The Atlas booster again failed in the launch of Intelsat 4AD in September 1977.

With the launch of Intelsat 4AB in January 1976 the Centaur achieved its 35th successful flight and was the 20th stage in geocentric orbit [2].

Titan-Centaur

Previous to this, the Centaur had been combined with the Titan launch vehicle in a modified form.

The Titan Centaur IIIE was designed to launch payloads which fell in the gap between the Atlas Centaur and the very expensive Saturn IB and has been used to launch the payloads given in Table 2. Its work will be taken over by the Shuttle but in 1969, when NASA still had the Viking Mars missions to find a launch vehicle for, the Titan Centaur combination was an attractive prospect.

General Dynamics was given a contract to develop a modified Centaur for further use with the Atlas (the Centaur designated D-1A) or with the modified Titan III (the Centaur designated D-1T).

The D-1T is 9.60 m (31.5 ft.) long and 3.05 m (10 ft.) in diameter and employs two RL-10A-3-3 engines giving 6804 kgf (15,000 lbf) thrust each. Total fuelled weight is 16,258 kg (35,843 lb.). Since the D-1T was designed to perform complicated restart missions it has to be able to coast for long periods with the Sun heating the propellant tanks; multi-layered aluminised mylar and dacron insulation panels are used to reduce fuel evaporation.

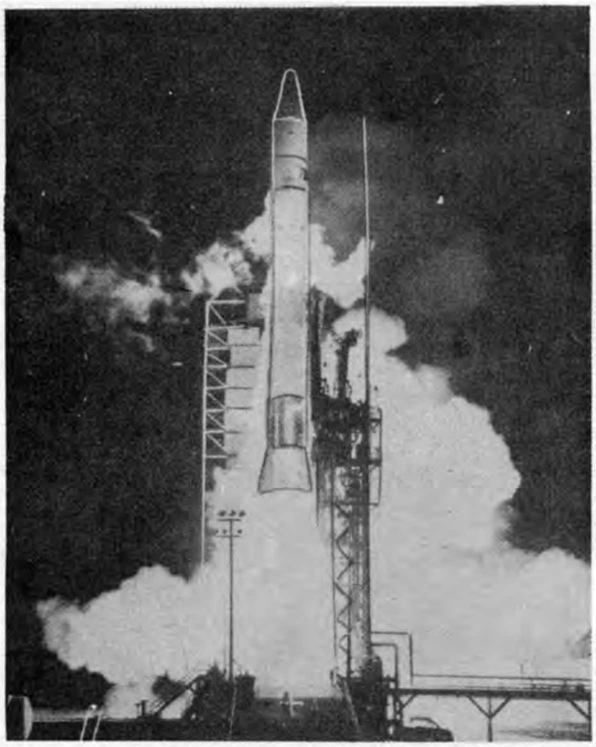
Small hydrogen peroxide thrusters are used both for attitude control and for vehicle separation at payload release.

A 16,000 word Teledyne computer and a four gimbal Honeywell inertial reference unit control navigation, guidance, propellant and tank pressure management, telemetry for transmission and general vehicle performance. Ground commands are now routed through the Centaur guidance system to the Atlas or Titan III.

The Centaur Standard Shroud covers the entire D-1T stage to improve payload capacity within the 17.6 m (58 ft.) long and 4.2 m (14 ft.) diameter shroud, constructed of steel, magnesium and aluminium. The two halves of the CSS are separated from the rest of the vehicle about 10

Table 2. Titan Centaur launches.

Sequence Number	TC Number	Mission	Comments
1	1	Test	Centaur failure
2	2	Helios 1	+ TE-M-364-4 fourth stage
3	4	Viking 1	Mars lander/orbiter
4	3	Viking 2	Mars lander/orbiter
5	5	Helios 2	+ TE-M-364-4 fourth stage
6	7	Voyager 2	Outer planets mission
7	6	Voyager 1	Outer planets mission



AC-26 carrying Intelsat 4B into orbit on 19 December 1971. The Atlas is the SLV-3C type, serial number 5006C.

seconds after Titan stage 2 ignition, using new non-contaminating pyrotechnics and four springs, leaving behind a cylindrical section of the CSS attached to the Titan. The D-1T sits on a 2.9 m (9.5 ft.) long Interstage Adapter until the Centaur guidance system begins separation procedures by igniting a charge in the Adapter. The Centaur engines then ignite 10.5 seconds later.

Missions

The first Titan Centaur mission was for engineering purposes to test the Centaur and other systems in a three-burn synchronous orbit mission, carrying a SPHINX spacecraft which was to test high voltage equipment. The well tried Titan stages functioned well but ground crew could see no sign of Centaur ignition and the range safety officer had to destroy the vehicle. The Centaur guidance system, which was to have initiated ignition events, was immediately under suspicion. The launch had been delayed from early 1974 because of vibration problems with the guidance system.

Despite this failure, NASA did not schedule a further test flight but went ahead with the launch of Helios 1 on 10 December 1974. At T+320s the shroud separated from the Centaur stage, followed at T+24m by the Centaur's first burn, of 38 seconds, putting the payload/upper stage into a nominal parking orbit. A 273 second burn ther took the combination into a 157,261 km x 1,764 km x 31°77 (97,500 mile x 1,090 mile x 31°77) parking orbit. Helios 1 and the TE-M-364-4 fourth stage separated from the Centaur and while the final stages went on to complete their missions the D-1T began a separate programme of tests. Following a one hour coast period without thruster firings to settle the propellants, the thrusters were then fired before the Centaur engines ignited for 11.4 seconds. A further three hour coast was carried out, followed by the main engines firing for 46.3 seconds. To date, this was the most complex unmanned flight carried out. Later missions were even more complicated. TC-5, for example, performed seven ignitions of the Centaur main engines. Table II gives the mission listing for TC flights. The nominal event schedule for the Centaurs in the Voyager launches were as follows:

T+261s	Stage 2 ignition
T+271s	Centaur shroud jettison
T+488s	Centaur main engine starts (MES 1)
T+590s	Centaur main engines cutoff (MECO 1). Begin Coast.
T+2545s	Centaur MES 2
T+2888s	Centaur MECO 2
T+3510s	Start post-MECO 2 coast
T+3680s	Centaur-spacecraft separation.

Table 3. A-C and other vehicle capabilities.

Atlas Centaur	
	1814 kg (4,000 lb.) to geostationary transfer orbit
	590 kg (1,300 lb.) on Earth escape
Titan Centaur	
	6800 kg (15,000 lb.) to geostationary transfer orbit
	4014 kg (8,850 lb.) on Earth escape
Delta 2914	
	680 kg (1,500 lb.) to geostationary transfer orbit
	386 kg (850 lb.) on Earth escape
Scout D	
	177 kg (390 lb.) to 480 km (300 miles) orbit.

Conclusions

The Centaur upper stage is now nearing the end of its useful life, both with the Titan and Atlas first stages, but has yet to launch further Intelsats and the Pioneer-Venus probe this year. Its work with the Atlas will be taken over by the Shuttle in combination with the solid fuel SSUS-A (Spin Stabilised Upper Stage-Atlas class), the first flights of which will place Intelsat 5 and Comsat communications satellites into orbit. As presently projected [3] the cost of carrying one payload will be about $28 million, as compared to the $33 million of the current Atlas Centaurs.

Acknowledgements

The author wishes to express his thanks to the staff of the Public Relations Department of General Dynamics, Convair Division, for their help in the preparation of this article.

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The Editor is always interested in receiving items of correspondence, notes, comments, or reviews for possible publication. Items submitted must be kept brief.

MAKING CLOUDS IN SPACELAB

By Christine Duncan*

Introduction

Why can't we get an accurate weather prediction? Because we can't see what's going on inside the clouds as they form, says Dr. Bernard Anderson, a cloud physicist in the Space Sciences Lab at Marshall Center. "Two clouds may look alike as they begin forming. Yet, one will bring a gentle, nourishing rain and the other will leave the ground dry and parched."

Dr. Anderson and his colleagues theorize that the differences stem from microphysical processes within the clouds that alter the release of energy through condensation. "To accurately predict the weather, or to do anything about changing it," he said, "we must first understand these microphysiçal processes."

Great strides have been made recently but scientists are up against a brick wall in their attempts to observe the multitude of cloud formation processes. In experiment cloud chambers on Earth, either the gravity effect or the techniques used to overcome it mask observational results. Measurements are difficult and approaches are limited.

Now, in a new programme managed by the Marshall Center, NASA proposes to do something about breaking down that brick wall by providing an important new research facility in which gravity infuences will be reduced greatly.

The Marshall Center has established a project office that is responsible for developing an Atmospheric Cloud Physics Laboratory (ACPL). This laboratory will be carried into space in the Spacelab in the early 1980's. In this facility scientists can, for the first time, study cloud physics without gravitational disturbances.

"This laboratory in space," said Charles R. Ellsworth, manager of the project, "will allow investigators to study the way clouds form more closely than has ever been possible on Earth."

* *Public Affairs Office, Marshall Space Flight Center, Huntsville, Alabama.*

Microscopic Processes

For at least 35 years, scientists have tried to study the behaviour of molecules, atoms and elementary aerosol particles, and the way these minute particles cluster to form the beginning of condensation. As clusters develop into microscopic cloud drops, at least a million of them must combine to form a single raindrop. Whether a raindrop will form depends on the surface, electrical, chemical and aerodynamic properties of the cloud drops, as well as their number and density.

ACPL investigators will be able to examine microscopically many of these properties and other factors such as temperature, growth of ice crystals and formation of electrical charges. These are some of the processes that determine how long a cloud will last, how high it will build and how much precipitation it will produce.

Gravity Infuence

All these processes have already been examined in some detail. The experiments have been done under conditions that are not at all like those in a cloud. Results are influenced by the experiment chamber walls and other hardware.

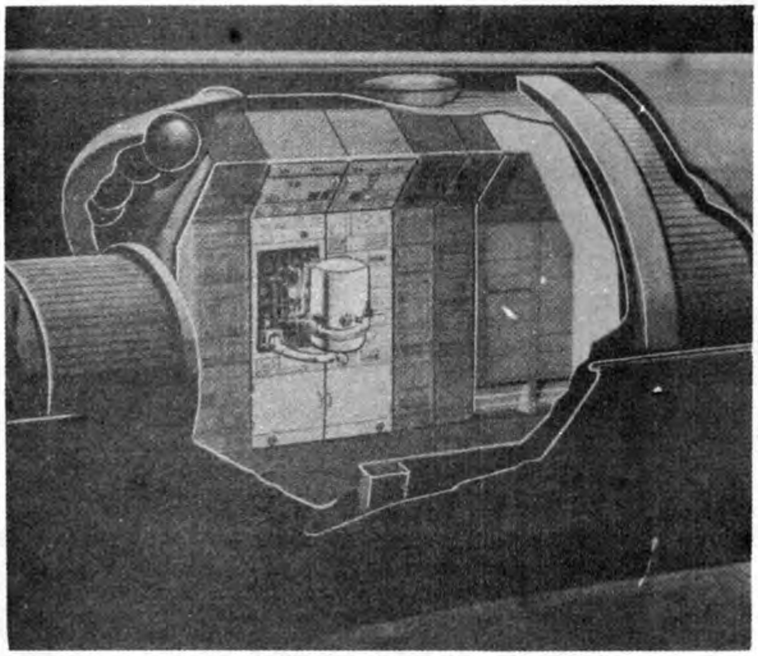
On Earth, raindrops and snowflake-size particles fall rapidly to the bottom of the chamber. Attempts have been made to capture and suspend the drops by placing them on wax paper or sheets of copper or stainless steel; they have been hung on a thermocouple and suspended on a spider web or a thread.

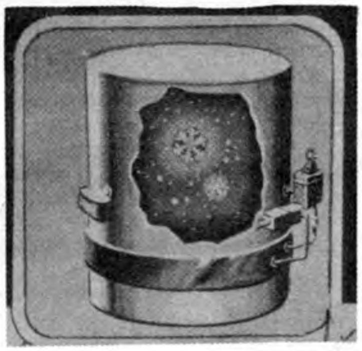
All of these foreign materials create disturbances greater than the effects the investigator is trying to measure. In addition, undesirable air currents are caused by chamber wall disturbances.

Comparisons between observations in the Earth-based laboratory and what is apparently happening in actual clouds, in some cases, have no correlation whatsoever.

Problem Solved

The project scientist for ACPL, Dr. Robert E. Smith of the Space Sciences Laboratory, indicated that cloud physics





Above, Artist's impression of cloud chamber showing formation of crystals.

Left, Atmospheric Cloud Physics Lab in a Spacelab module carried in the Shuttle cargo bay.

Artist's impression of payload specialist operating an ACPL experimental cloud chamber in a Spacelab module.

MSFC

investigators are very enthusiastic about the opportunity to perform experiments in the new laboratory.

In the ACPL facility, a microscopic element can be suspended without support. The processes of freezing, thawing, collision, electric charging and temperature changes can be observed and photographed as many times and for as long as necessary.

Prediction and Modification

Dr. Anderson, whose experiment is one of three to be performed on the first ACPL mission, said, "These observations will enable us to define many of the processes in clouds that are not understood today. When we have this knowledge we will have moved a step closer to understanding how outside agents, when put into clouds, will alter the natural processes of formation in a predictable way."

Dr. C. L. Hosler, who, in 1967, originated the proposal for a space-based cloud physics laboratory, is dean of the College of Earth and Mineral Sciences at Pennsylvania State University. He said, "It is plausible to me that within the next century we will be preventing something like a tornado or squall line. We could, by remote sensing, determine which clouds to seed so that they cannot let that single cloud form which produces the thunderstorm."

Dr. Hosler also predicts that eventually programmed releases of rainfall will be possible with knowledge gained from studies like the ACPL experiments. "For instance," he said, "we might be able to programme small raindrops instead of the large ones that cause soil erosion; or release rainfall into a watershed where the run-off can be controlled."

First Mission

The first ACPL mission is planned for Spacelab 3, tentatively scheduled for flight in June 1981. Marshall Center will be responsible for all project-oriented activities associated with launch preparation, launch, flight operations support and post-flight activities.

The experimenters will participate actively from launch preparation to Shuttle/Spacelab landing, and a two-way voice link between them and the payload specialists will be provided.

MILESTONES/*continued from page 321]*

21 Cosmonauts continue reactivation of Salyut 6 in stages. They have checked the propulsion system which orientates and manoeuvres the station. They report that they have already prepared their first cup of tea from water regenerated from condensation. In the afternoon they made a complete check of their blood circulation using installed equipment.

26 Cosmonauts Vladimir Kovalyonok and Alexander Ivanchenkov complete three-day experiment with the Splav-01 furnace in the airlock chamber which is open to space.

27 Soviets launch Soyuz 30 from Tyuratam at 18.27 hours (Moscow time) with Col. Pyotr Klimuk of USSR and Major Miroslaw Hermaszewski of Poland to undertake joint experiments with cosmonauts Kovalyonok and Ivanchenkov already aboard Salyut 6. Major Hermaszewsky, a fighter pilot in the Polish Air Force, began training for space flight at the Gagarin Cosmonauts' Training Centre in 1976 under the Intercosmos programme. Another Polish trainee cosmonaut Zenon Jankowski is assisting the flight director at Kalinin Mission Control.

28 Soyuz 30 docks with Salyut 6/Soyuz 29 combination at 20.08 hrs (Moscow time). Experiments include manufacture of semi-conductors, bio-medical effects of weightlessness on human organism, photography of Earth, and work related to functioning of individual systems of complete space complex.

July

1 Salyut 6 cosmonauts complete joint Soviet/Polish technology experiment 'Sirena' in the Splav furnace which aims to obtain cadmium-mercury-telluride (CMT) semi-conductor material in conditions of microgravity.

2 Cosmonauts Klimuk and Hermaszewski carry out "heat exchange experiment comparing their sensations to instrument readings;" also an experiment on the 'space bicycle' using a Polish-designed instrument to record cardiovascular reactions using the Chibis pressure suit and the Polynom-2M equipment.

3 Cosmonauts use the Zeiss MKF-6M 'multi-zonal' camera to photograph areas in the European USSR, Kazakhstan and the oceans. Photography includes area of Poland in conjunction with photos taken simultaneously from an aeroplane and helicopters. Cosmonauts also carried out a further Polish-Soviet technology experiment with the Splav furnace. Also, a psychological experiment 'Relaks' to find the most favourable conditions for rest in orbit. Orbit of space station complex is 330 x 360 km x 51.6 deg; period 91.2 min.

5 U.S. House of Representatives votes by 267 to 6 to approve expenditure of $25 million (£13 million) in FY 1979 for research and development on satellite solar power stations. If approved by the Senate, the money will allow work to begin on test systems to be launched by the NASA Space Shuttle.

5 Soyuz 30 cosmonauts Pyotr Klimuk and Miroslaw Hermaszewski undock from Salyut 6-Soyuz 29 at 13 hr 15 min (Moscow time); they soft land 300 km west of Tselinograd, Kazakhstan.

7 Soviets launch unmanned supply craft Progress 2 from Tyuratam cosmodrome at 14 hr. 26 min (Moscow time). Contains fuel, supplies and mail for transfer to Salyut 6.

T 16

HARRY ERNEST ROSS

A MAN OF VISION

HARRY ROSS, who recently died at the age of 73, after a long illness, was a pioneer of the practice and philosophy of Astronautics. A modest man of outstanding vision, he was one of a famous band of dedicated British enthusiasts who saw Man's conquest of space as a key element of human evolution.

Harry joined the British Interplanetary Society after the Headquarters moved from Liverpool to London in 1937 and played a leading role in shaping technical policy in the formulative years.

He was a member of the Technical Committee responsible for the BIS Lunar Spaceship study of 1937-39, participated in the rebirth of the Society after World War II, and became a Fellow and Council Member.

Looking back nearly 40 years Harry recalled how the requirements of a round trip to the Moon had gripped his imagination:

> *"I have no doubt that other members of the BIS, from its inception in 1933 by P. E. Cleator, down to the present, have experienced the same powerful emotional attraction to the conquest of space – to what has indeed come to be the greatest technological achievement of all the ages. Many will have found, like myself, satisfaction in being a member of a Society which has risen triumphantly from general ridicule of its ideas to a high degree of scientific and popular acclaim..."*

HARRY ROSS (1904-1978) receives BIS Bronze Medal "for outstanding contributions to Astronautics" from the Society's President Professor G. V. Groves on 9 June 1971. On the nomination of the BIS, Mr. Ross was elected a Corresponding Member of the International Academy of Astronautics in the Engineering Sciences Section in 1968.

Early Career

Harry began his career as a laboratory assistant in the Prosectorium of the London Zoo. Highlights of this occupation (he recalled later) included pulling the lion's tail, birds' nesting round the Mappin Terraces, finding a live python on the roof of the Reptile House – and learning to shoot with a .45 Webley. In his spare time he also learned how to make microscope slides and became adept at skinning anything from humming birds to tigers.

Later, Harry went to the London School of Tropical Medicine and Hygiene, where, in the Department of Helminthology, he worked under the direction of Professor Leiper.

By then the early experiments in radio broadcasting began to take more and more of his interest. In 1920-21 he studied radio and obtained a P.M.G. certificate. Three years later he entered the Marconi International Marine Communications Company as an operator and went to sea, sailing to South Africa, Ceylon, India and South America.

Foresaking the sea for the even more precarious existence of factory life, Harry worked for a time in the Radio Inspection Department of the New Southgate (London) works of the Western Electric Company; later he accepted an appointment with A. C. Cossor, and eventually took charge of the manufacture of all "mains" type radio valves.

In 1926 Harry married Eva Bright but to his great sorrow she died of TB in 1932. He did not remarry.

The big demand for radio equipment during World War II made his experience invaluable and in 1941 he went to High Wycombe, Buckinghamshire, to initiate the training of labour for a shadow factory operating under the management of A. C. Cossor, later becoming Production Control Superintendent.

It was then that he became convinced of the role that Space would play in shaping human destiny; and friendship with another early member of the BIS, the late Ralph A. Smith, was to lead to some of the most perceptive studies in Astronautics of the early post-War era. In 1946 they revised the original design for a Moon-landing vehicle in the light of liquid propellant technology, and then worked on designs for a man-carrying rocket based on a modification of the German V-2 (*JBIS*, May 1948).

The latter included detailed engineering proposals in which a pressurized capsule would separate from the rocket and reach heights of up to 225 miles (362 km) to test the occupant's reactions to launch accelerations and short periods of zero-g. The capsule could be spun about its vertical axis to simulate gravity before finally being recovered by parachute.

Plans submitted to the then U.K. Ministry of Supply on 23 December 1946 failed to elicit Government support. However, in 1961 their work was vindicated when the United States adopted a similar solution in the Redstone-Mercury rockets which gave Alan Shepard and the late 'Gus' Grissom sub-orbital experience of space flight.

Another major contribution – this time almost wholly worked out by Harry himself over many years – was a detailed design of a spacesuit for use on the Moon ('The Lunar Spacesuit.' *JBIS*, January 1950).

Harry and Ralph also produced, in considerable detail, the design of a manned space station powered by solar energy. This study formed the basis of the paper 'Orbital Bases' (*JBIS*, January 1949) which also outlined a method for landing on the Moon using a space vehicle refuelled by unmanned telecontrolled 'tankers' in lunar orbit.

Despite recurring ill-health (both he and Ralph contracted tuberculosis during the War), Harry continued to devote much of his spare time to space studies.

In 1969, after a long spell in a Surrey chest hospital, his condition was so poor that doctors gave him only two years to live. But Harry did not quit the fight, and during the next *eight* years, despite severe lung impairment, he developed his philosophy of Astronautics in a series of articles for the Society. His final contribution 'Quo Vadis' – written a month before he died on 8 May 1978 – appeared in the July issue of *Spaceflight*.

Kenneth W. Gatland

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

SHUTTLE MAIN ENGINE

Although the first launch of the Space Shuttle will be delayed three months because of problems in developing its main engine, there are none that should bar development of a safe engine. This was revealed in March at a Senate hearing on a National Research Council investigation into problems that have hampered the engine programme. Meanwhile, three major engine firings are bringing the troubled programme closer to an intensive test effort that should make up for lost time and lead to preliminary flight certification in early 1979, writes Dave Dooling.

Dr. Robert Frosch, NASA administrator, told the Senate Committee on Commerce, Science and Transportation on 31 March there was "less than a 50-50 chance" of making the March, 1979 date. "There is still a reasonable expectation that the engine can be certified for the first development flight in mid-1979," he told the committee. NASA is now working to a launch date at the end of June.

The Senate committee requested the investigation which was conducted by the National Research Council of the National Science Foundation. Committee chairman Adlai Stevenson III and ranking minority member Harrison Schmitt were concerned that the engine problem might seriously delay the Shuttle programme.

The main engine is the most complex and sophisticated liquid propellant engine ever attempted. It must operate on 50 flights for more than eight minutes each before a major overhaul. Chamber pressure is almost 5,000 lb/in^2 (351 kg/cm^2) in the preburners and specific impulse is 456 seconds, the highest of any production engine yet. Thrust is 475,000 lbf (2,112,800 newtons (vacuum)).

The engine uses a preburner burning cycle to achieve its efficiency. A portion of the liquid oxygen is burned with most of the liquid hydrogen in two preburners, one each for the high pressure oxidizer and fuel turbopumps. This hydrogen-rich steam is fed directly into the main combustion chamber where the remainder of the liquid oxygen and liquid hydrogen are added.

Several mishaps have marred the development firing programme. During 1977 there were several premature shutdowns because of instrumentation problems. Two fires broke out during test runs, one because of a failure in a dynamic seal separating hot gas from liquid oxygen. Neither resulted in injuries or severe damage, but consumed time while tests were halted to analyze the problem and develop a fix. The high pressure fuel turbopump also experienced severe turbine tip seal erosion and blade fatigue. However, an earlier subsynchronous whirl problem which caused excessive vibration in the main shaft had been solved.

Despite these problems, the chairman of the blue-ribbon investigating committee and the project officer were optimistic. "The bottom line is that there's no fundamental problem that says they can't build a safe engine," said Albert J. Evans, the committee's project officer and a professional associate with the council. "The feeling is that the problems they are running into are the kinds of problems they would run into," on any major rocket programme, and not a result of poor management.

Both Marshall Space Flight Center, the development centre, and Rocketdyne Division of Rockwell International, the prime contractor, deserved high marks for management, he added. Eugene Covert, the chairman and a professor of engineering at Massachusetts Institute of Technology, stressed that in such a programme there is no such thing as "automatic development." "I think that at this point in the programme the thing to do is let the engine tell us what its development state is" by waiting for the results of intensive testing scheduled through the year, "and not try to outguess it."

Recommendations by the investigators include:

Setting up a separate test stand just for the high pressure turbopumps rather than using the engines as test stands. Pump failures can cause damage downstream. A separate stand would allow the pumps to stay ahead of main engine testing and Shuttle flights.

Drawing up an alternative design for the high pressure oxidizer turbopump.

Testing the engines used on the first manned orbital test flight at two per cent above 100 per cent of rated power level (RPL), thus giving some margin of safety.

Complete tear-down inspections of all three engines after the first and sixth flights.

Closely watching the heat exchanger in the high pressure oxidizer turbopump. Evans said this offers a "single-point threat for catastrophe" if its fails.

Upgrade the engine to full power level (109% of RPL) as soon as possible. NASA is foregoing this difficult milestone until after it can get the engine operational. Limiting flights to RPL also limits maximum payloads and abort considerations.

A total of 80,000 seconds of test time must be accumulated by the first launch.

The engine programme took a turn for the better on 21 April, with the first successful firing of the main propulsion test article (MPTA), a full-scale working model of the main engine system. This was followed in May by a full-duration single-engine firing, and a second, longer MPTA firing.

The MPTA simulates the complete main engine system, including external tank, three main engines, plumbing, electronics, and Shuttle Orbiter aft thrust structure. The forward orbiter is simulated by a boilerplate structure.

All engine tests are conducted at the National Space Technology Laboratories at Bay St. Louis, Mississippi. This was formerly known as the Mississippi Test Facility and used during the 1960's for tests of Saturn-class engines. The A-1 and A-2 test stands are used for single-engine tests, and the B-1 test stand is used for MPTA.

The first MPTA firing on 21 April lasted for less than its planned 2.35 second burn time. After one second, an improperly plugged temperature sensor gave a faulty temperature reading and prompted a computer to shut the test down. However, the near-perfect countdown and the ignition (the main objective) gave engineers sufficient data to proceed to the next test, a 15-second firing. (The first MPTA attempt, on 11 April was frustrated several times by a broken microswitch indicating that an LH_2 prevalve was open and closed. Because safety margins were set conservatively, engineers were unable to work around this problem and postponed until 21 April).

The second MPTA firing was successfully attempted on 19 May. The engine cluster fired for 15 seconds and reached their desired goal of 70% RPL. The next objective was 90% RPL for 40 seconds.

While MPTA was proving itself, a single engine almost identical to flight configuration completed a full-duration run (520 seconds) at 100% RPL. The total impulse was actually more than the engine will deliver in flight because of throttling requirements. A test a few days later to achieve this failed after 123 seconds because of an instrumentation failure.

Dominick Sanchini, vice president of Rocketdyne, said this engine is essentially identical to the configuration that will be used in the first manned orbital flight. It uses the

77:1 expansion nozzle, pogo accumulator to prevent longitudinal vibrations, heavier bearings on the LOX turbopump, new LOX pump seals, lighter fuel turbine blade dampers, and better turbine blade tips. He said only the new LOX impeller and dampers have yet to be installed.

Around September, he continued, Rocketdyne hopes to install a qualification engine – identical to the flight engines – for a series of 20 tests accumulating 5,000 seconds of test time. Some will be start-stop tests, others will be full duration. Also in September, the MPTA is scheduled for a full-duration test with new turbopumps.

Sanchini said he feels the engine programme is about to straighten itself out and should be ready to support Shuttle flights in 1979.

"I feel a lot better than I did a couple of months ago," he said. "That MPTA test really boosted our morale.... It feels a lot better. (But) We've got a tough summer. We've got to prove we can do it over and over."

As it turned out the original Space Shuttle March launch date at Cape Canaveral could not have been met as the External Tank and Solid Rocket Boosters were also subject to delay. Ed.

Conservative M.P. Kenneth Warren during a visit to the Marshall Space Flight Center in Huntsville, Alabama, to see the Space Shuttle 'Enterprise' as it entered vibration tests. Warren is chairman of the Assembly of West European Union's Committee on Science, Technology and Aerospace. He said he hoped Britain's contribution to the European Space Agency will grow now that the nation is becoming a net exporter of petroleum.

Dudley Campbell, 'The Huntsville Times.'

'ENTERPRISE' AT HUNTSVILLE

Space Shuttle 'Enterprise' arrived in Huntsville, Alabama, on 13 March for several months of tests simulating launch vibrations, writes Dave Dooling. The mated vertical ground vibration tests (MVGVT), being carried out at Marshall Space Flight Center, bring together for the first time the major Shuttle components: Orbiter, External Tank, and Solid Rocket Boosters.

The 'Enterprise' has been installed in the dynamic test stand used for similar tests with the Saturn V during the 1960's.

In essence, MVGVT will make sure that the Shuttle does not shake itself apart during launch. Matthew Urlaub, MVGVT manager, said that anyone who has driven a car with an unbalanced tyre will be familiar with the purpose of the tests. "We are mapping the vibrations patterns, "looking for frequencies that tune in and either reinforce or dampen major modal characteristics." MVGVT will also measure how the Shuttle bends when the solid motor nozzles flex, so the guidance system can compensate.

The Orbiter's arrival at Redstone Arsenal Airfield was well attended by the area press and dignitaries. The same Boeing 747 jumbo jet used to launch the 'Enterprise' for landing tests brought it from Edwards Air Force Base, California, *via* Ellington Air Force Base outside Johnson Space Center at Houston, Texas. About 200,000 people came out to see the space plane at Ellington, and another 85,000 came out to see it and the external tank the weekend after the 'Enterprise' was removed from the 747 in Huntsville.

Demating was accomplished by way of a stiff leg derrick and a mobile crane. The 'Enterprise' was hoisted up a few feet, then the 747 was backed out and replaced with a strongback transporter. Then 'Enterprise' was lowered onto the transporter and, the next morning, transferred to the same hangar where the first two Saturn V S-IC stages were assembled. There, both the Orbiter and the tank were prepared for tests (the tank having arrived earlier on a barge from the Michoud Assembly Facility in New Orleans).

The start of tests was delayed several times for minor reasons. The tank was rolled to the test stand, then returned when a hydraulic portion of the hoist system broke. A second attempt was successful, followed by successful hoisting of the 'Enterprise.' Clearance was as little as two feet on the wingtips of the 78 ft. (24 m) span Orbiter as it went in. The two were mated on 3 April, the first time that Orbiter and External Tank have been brought together.

Rain further delayed the start of tests, postponing efforts by technicians to attach sensors. The most recent problem was a dimple in the liquid oxygen tank part of the external tank. This occurred during the weekend of 13-14 May while deionized water was being pumped in. Air displaced by the water was vented near the top of the test stand. High winds blowing past the vent apparently created suction around the vent, lowering air pressure inside the tank to the point that outside air pressure deformed the thin aluminium. Positive pressurization to 1 lb/in^2 (0.07 kg/cm^2) above atmospheric popped the dimple out without apparent damage.

Propellant loading procedures have been changed to prevent a recurrence of this.

The MVGVT series will involve a lot more than shaking the Shuttle to see what happens. There are five test modes, three requiring major shifts of hardware, and 56 shakers pushing and pulling with up to 1,000 lb. (4448 newtons) of force.

The first sequence simulated flight from booster jettison at T+122 seconds to main engine cutoff at T+520 seconds. Two to 50 tons of water were used to simulate various levels of liquid oxygen (liquid hydrogen will not be simulated because it is so light and adds little to the vibrations).

To hang the 'Enterprise' and tank so that it appears to be in flight, the pair are suspended from 24 air bags on an 85-ton beam. The attach point is the forward booster attach point on the tank. This leaves the pair canted slightly backwards. The beam deflects a full inch under the 1.2 million lb. (0.54 million jg) load.

After the six-week test sequence, the pair will be taken apart and returned to the hangar. Two full solid rocket boosters – with potassium chloride salt replacing the ammonium perchlorate oxidizer – will be installed, segment by segment. Then the tank and 'Enterprise' will be reinstalled.

Because this will, for the first time, duplicate assembly of the Shuttle at the launch site, crews from Kennedy Space Center are being used.

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THE SPACE TELESCOPE - A GIANT STEP IN ASTRONOMY

By Dr. C. R. O'Dell*

Astronomy deals with the most fundamental issues that face reasoning man: how did my world come into being, what is the order of the Universe and what role does my world play, what lies ahead for me and my descendants?

Answering these questions is the challenge to the astronomer, the theologian and the philosopher, and one cannot proceed without the other. The astronomer seeks to learn and understand the laws governing the structure and evolution of his Universe by observation and interpretation.

The astronomer's capacity for observation will be tremendously enhanced by NASA's Space Telescope, a multipurpose optical telescope in Earth orbit which will enable man to gaze seven times farther into space than has now been done, possibly to the outer edges of the Universe.

The scale of distances to even the most nearby stars is so great as to prevent modern man from visiting them for study. This means that the astronomer is only an observer – not an experimenter. He cannot punch, squeeze, melt, or perform operations on his subjects, but must learn only from observing what nature is doing.

Fortunately, the same vastness of scale that prohibits our travel also allows a richness of conditions to apply and a host of different observable phenomena to occur. For example, we can study regions of ionized gas that are so rarefied as to surpass the best vacuums achievable on the Earth; and we can study collapsed stars, stars so dense that all of the Earth could be compressed with equal density into a sphere only 1,000 ft. (305 m) in diameter.

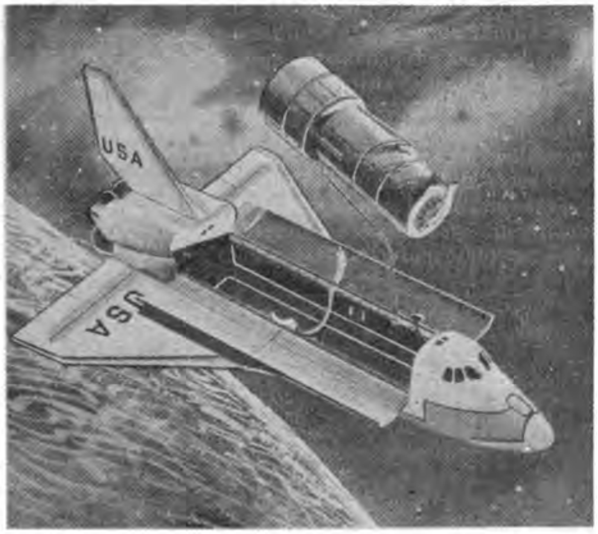
The plethora of observable objects can also be used to advantage. Although most of the phases of the evolution of a star like our Sun are very long compared with the total lifetime of men on the Earth, by observing individual stars in different phases of their changes, the astronomer can accurately picture the Sun from cradle to grave. Even though the Universe is abundant in its phenomena and subjects, the observational nature of this science means that the astronomer's "eyes" are only as good as his imagination and success in conceiving and realising new ways of observing.

The view of a docile Universe, composed of gravitational processes in stars and systems of stars (galaxies), has given way in the past 20 years to the more accurate picture of a violent Universe, filled with many cataclysmic events accompanying the origin of galaxies and the death of stars. We now know of quasars, neutron stars and possibly black holes, each of which gives off signals of its nature and existence with no regard for the sensitivity of the eyes of the most intelligent species, or for the properties of the atmosphere of the third planet of a rather common star, located two-thirds of the way out in a rather common kind of galaxy.

This means that if we are to get a complete view of the real Universe, we must continue to build powerful telescopes and to observe from space itself, where we see the Universe as it really is, not filtered by the terrestrial atmosphere.

It can be argued that astronomy is an esoteric science, justifiable only on the grounds of fundamental curiosity; however, there is further justification in its study of unique phenomena. Nature provides conditions that cannot be duplicated on the Earth and conditions whose cost to duplicate would be prohibitively expensive for basic research.

This means that we find conditions that stretch our current understanding of natural laws. The history of science shows that it is when the existing laws are put to the greatest tests that the greatest advance in understanding occurs. This raises the real possibility that fundamental processes first understood from astronomical observations can eventually be applied to aid the Earth and its population.



THE SPACE TELESCOPE to be placed in orbit in 1983 by the NASA Space Shuttle promises revolutionary advances in our understanding of the Universe.

Lockheed Missiles & Space Company

For example, the concept of nuclear fusion, which has the potential for solving the world energy crisis, was first confirmed by observation, over 40 years ago, of our Sun and other stars. These stars shine with energy generated by a process we are only now beginning to master here on the Earth.

Perhaps even more important secrets lie in the study of quasars. Like pre-nuclear fusion studies of the Sun, we do not now understand their basic source of energy, which in at least one case exceeds that of the Sun by 1,000,000 million times! Whether this energy mechanism can be used will not be known until these puzzling objects are understood and this will only occur if they are attacked with the most modern approaches to observations.

All types of observations are possible, from low-energy radio waves through the ultra-high-energy gamma rays; but, the greatest supplier of astronomical information is the optical telescope. However, the conditions of working in the Earth's gravity and through the turbulence of the Earth's atmosphere impose practical limitations in all but a very selected few types of observations. This means that the only practical successor to the giant Earth-based telescopes is the high-quality space telescope.

The Space Telescope project will provide such a telescope. Launched into Earth orbit by NASA's Space Shuttle in 1983, the Space Telescope, high above the hazy and turbulent atmosphere, will enable scientists to see the heavens clearly for the first time.

The Space Telescope is a superb system that fully exploits the advantages of space observations and will dramatically extend our capabilities beyond ground-based telescopes. It is a natural next step to take in the current revolution in astronomy, a revolution that history will probably equate with that of the Copernicus system 500 years ago.

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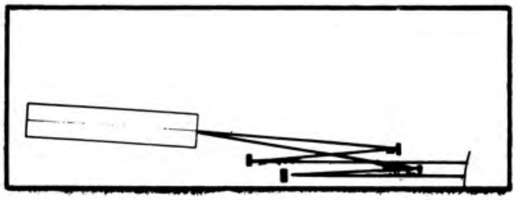
* *George C. Marshall Space Flight Center, Huntsville, Alabama.*

TELESCOPE OPTICS. Light enters the open end of the telescope, is projected by the primary mirror onto the smaller secondary mirror, and, from there, is deflected to the scientific instruments for analysis.



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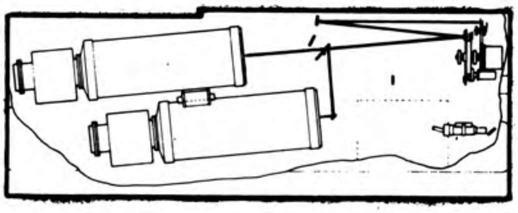

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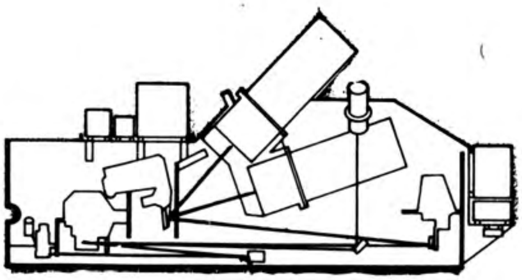

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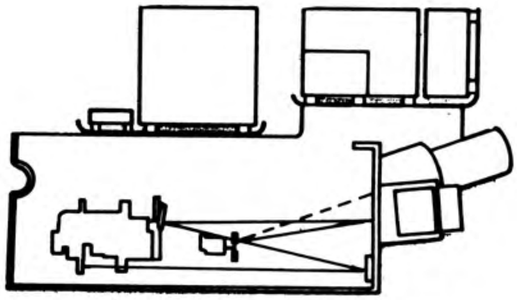

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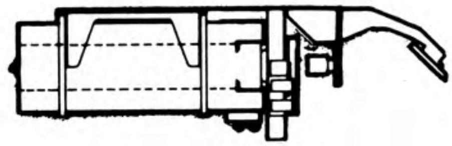


E

A. *A faint-object camera* will make images of very faint light sources.

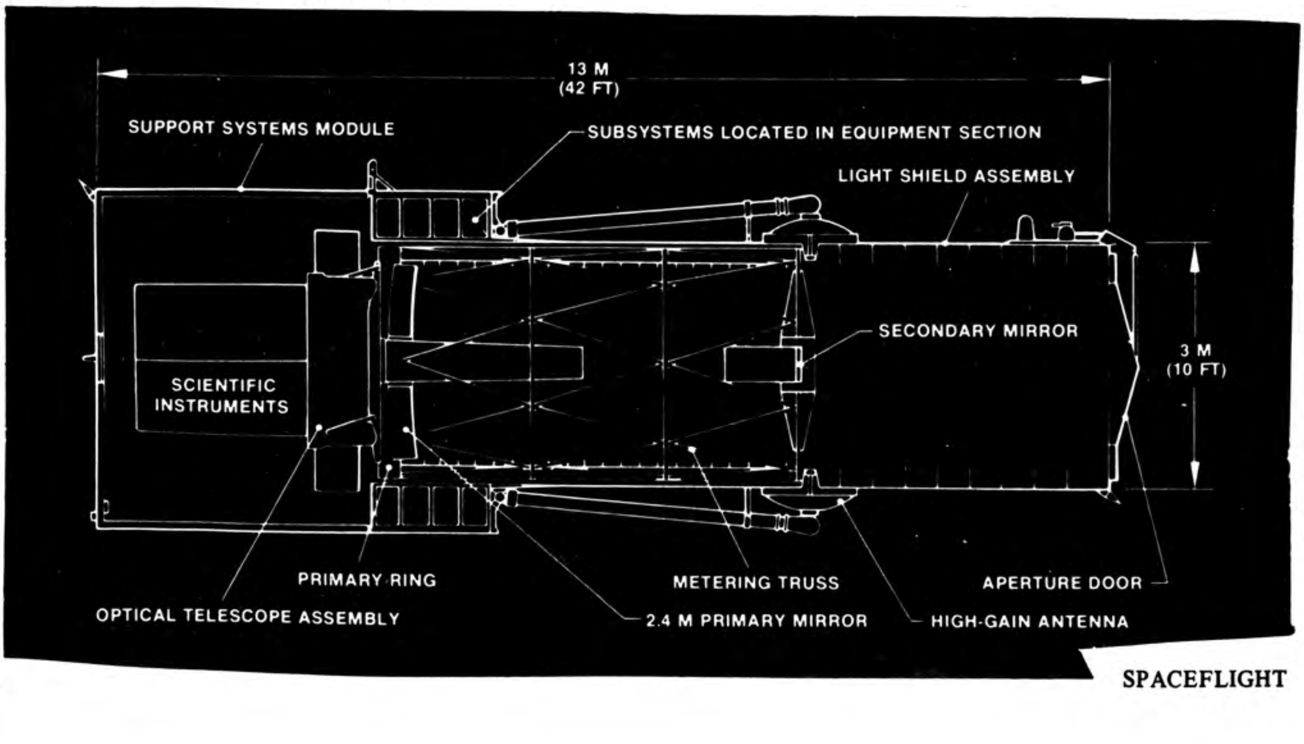
B. *A faint-object spectrograph* will measure the wavelengths of energy coming from faint sources.

C. *A high resolution spectrograph* will perform spectroscopy of point or extended sources in both ultraviolet and visible light.

D. *A high speed area photometer* will obtain precise measures of constant or time variable intensities over a broad wavelength interval from either point sources or celestial fields of small angular size. One of the three fine-guidance sensors, which are part of the Optical Telescope Assembly, will provide for astrometry – measurement of the positions and motions of stars.

E. *A wide-field camera* will make images of celestial objects.

Below. The Space Telescope: principal features.



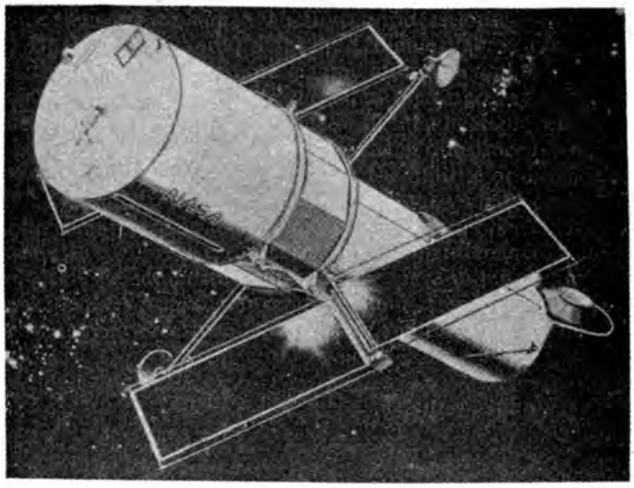
THE SPACE TELESCOPE

By Geoffrey Hugh Lindop

Introduction

THE SPACE TELESCOPE will be a reality in the early 1980's. On 6 October 1976, the European Space Agency's Science Programme Committee approved plans for European participation in this project subject to the formal go-ahead being given by the United States for FY 1978 [1]. That confirmation was given by Mr. H. Huyford Stever, director of the President's Office of Science and Technology Policy on 14 December 1976 [2].

A memorandum of Understanding was signed at ESA Headquarters in Paris on 7 October 1977 by Mr. Robert A. Frosh, Administrator of NASA, and Mr. Roy Gibson, Director-General of ESA [3]. Under the terms of the Memorandum, Europe will provide the faint-object camera, the solar array, and will participate in the support of the Space Telescope Science Institute, the body concerned with the scientific operations of the Telescope. In return European astronomers will be granted at least 15% of the observing time of the Telescope.



Parameters of the Space Telescope

The primary mirror will have a diameter of 2.4 metres (94 in.). This compares with the 2.5 metre (98 in.) Isaac Newton Telescope, but is somewhat smaller than the 3.8 metre (150 in.) Infra Red telescope on Mauna Kea, Hawaii, which comes into operation this year.

The original plan for the Space Telescope, was in fact for a 3 metre (118 in.) objective, but this would have been too expensive. Studies were also made of a 1.8 metre (71 in.) system, but the savings on this compared with a 2.4 metre (94 in.) would have been minimal, and the loss to the scientific community would have been great. In May 1974, therefore, NASA opted for the 2.4 metre as being the optimum size to balance costs against scientific value.

The angular resolution of the Telescope will be 0.1 seconds of arc, or something like 300 km on the surface of Jupiter when the planet is at opposition; or 2,800 km on the surface of Pluto, when that planet is similarly placed. Expressed another way, the Telescope will be able to resolve a florin (10p coin) 600 km away. It would, therefore, provide comparable pictures to a planetary flyby mission, such as Pioneer 10 and 11, but not as good as a lander mission such as Viking.

The Telescope can only make use of such a good resolving power by virtue of its position above the atmosphere, where it is free from air turbulance. Even photographs of the planets taken with the 5.08 metre (200 in.) telescope on Mount Palomar are seriously degraded by the atmosphere. That is not to say that an orbiting telescope has absolutely perfect 'seeing' conditions, light scatter from the Sun, Earth and Moon being the main elements to be avoided Fortunately, by carefully planning the observing schedule, these factors can be reduced to zero.

The attainment of the above resolution can only be met if the telescope can be securely stabilised. This is the old criterion of the telescope being only as good as its tripod, but of course, an orbiting satellite cannot be bolted securely to the ground and stabilisation becomes a real problem. The working parties investigating the development of the Space Telescope have come up with a figure for the required stability of 0.007 seconds of arc. If the Telescope is represented by a rigid beam 1,000 km long, the stability is such that the one end of the beam might be raised by no more than 3 millimetres!

At present such stability is beyond our technology. The OAO satellite, for example, attained a stability of only 0.01 second of arc. Nevertheless the engineers and technologists involved in the Space Telescope programme are confident that this goal can be met be careful planning. Typical of one of the problems they face is the communications antennae. The very act of tracking to maintain alignment of the microwave beam will generate a torque and disturb the stability of the telescope too much. Yet if the microwave dish is replaced by a dipole such that the radiation pattern is omni-directional, then the radio signal would interfere with other users with similar radio frequency allocations. The compromise seems to lie in a very balanced microwave dish that will not generate torque as it moves.

It is perhaps fitting that an instrument designed to observe celestial objects should have parameters of such astronomical proportions; but the most staggering statistic relating to the Telescope is its signal-to-noise ratio of approximately 5×10^5. It is claimed [5] that to achieve the same sort of figure from ground-based telescopes would require 2.5×10^{11} individual exposures (or some 800 years of exposure time) to match the performance of the Space Telescope in just one orbit. In light grasp alone, the Space Telescope scores over its cousin on Mount Palomar reaching stars of magnitude 26 or 27, that is 50 times fainter than the 200 in. telescope. It is staggering to speculate what mysteries of the Universe will be unfolded.

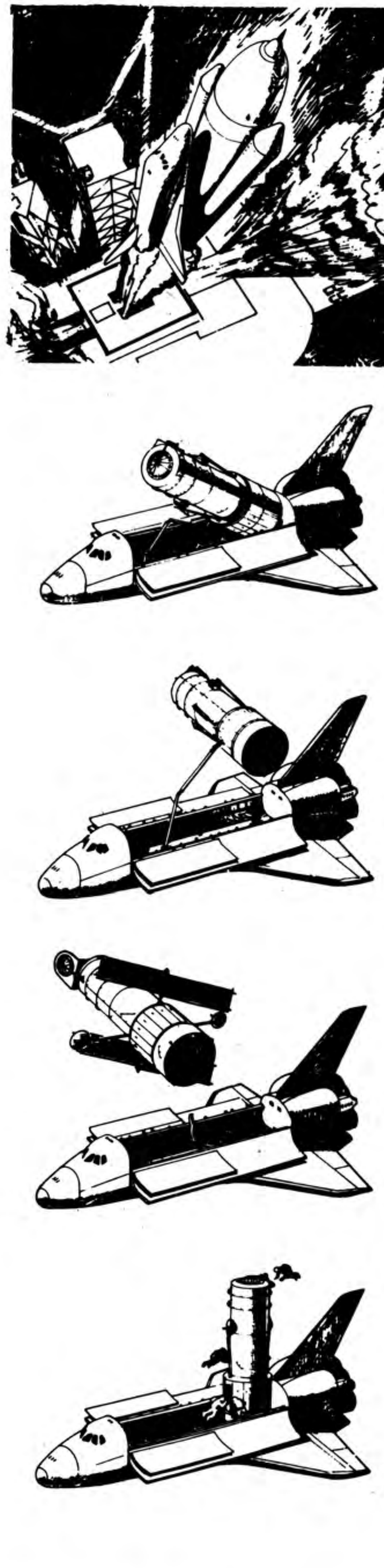
Operation of the Space Telescope

The Space Telescope is expected to be carried into orbit on the Space Shuttle in early 1983. The time is not critical since there are no launch window considerations.

When in orbit, about 520 km (320 miles) above the Earth, the Shuttle's remote manipulator arms will be used to erect the Telescope onto the sill of the cargo bay; the solar arrays and the antennae will then be deployed. After separation from the Shuttle, check out procedures are likely to take several days, with the Shuttle orbiting close by to act as liason with the ground and take whatever actions may be necessary to ensure successful operation.

Shuttles will revisit the Telescope for maintenance, which can either be administered in-orbit by space-suited technicians in an EVA mode, or on the ground after the Telescope has been recovered by a Shuttle crew and returned to the Earth.

[Continued on page iv



Handling the Space Telescope. Two reusable solid rocket boosters and an external propellant tank are required to launch the Orbiter into orbit.

THE UK CONTRIBUTION

British Aerospace Dynamics Group at Bristol have been awarded contracts worth £13.3M by the European Space Agency, for work on the Space Telescope which it is developing jointly with NASA.

There are two BAe contracts. One covers the development and manufacture of the Solar Array to power the whole Space Telescope during 10-15 years lifetime in space. It is by far the largest array ever to be developed in Europe and fully extended will be about 33 square metres in area and provide more than 4 kW of power.

The other contract is for the Photon Detector Assembly which is the heart of a Faint Object Camera, one of the five special observing instruments carried on-board. The camera will focus photons of light on to the Photon Detector Assembly, which will amplify the light of individual photons until their position can be recorded by a low light television camera tube. The signal from the camera tube will be analysed by a complex electronic pattern recognition logic unit to build up the image of the star.

There is a balance here between 'cheap' maintenance undertaken on Earth, which can take the telescope out of service for prolonged periods, and expensive in-orbit maintenance which will cause the minimum of disruption to the observing programme.

In-orbit maintenance will probably be carried out every one or two years. Such missions will replace batteries and components, particularly those damaged by radiation as the Space Telescope passes through the South Atlantic Anomaly, where the Earth's radiation belts dip towards the ground.

Every four or seven years the Telescope will be brought down to the ground for refurbishment. This will be done at the Marshall Space Flight Center where Building 4755 has been provisionally designated as the Space Telescope's Central Integration Site. During this period, the mirrors will be returned to the contractor for resurfacing.

Servicing of the remainder of the Telescope will require a specialist staff at MSFC and it would be more cost effective if this facility could be used for the refurbishment of other equipment during periods when the Space Telescope is operational.

The Scientific Institute

When the Telescope is operating in orbit, responsibility will lie with the Goddard Space Flight Center, where it is expected that the Space Telescope Scientific Institute will be installed. Alternatively, Institute staff might be co-located at another site and also at GSFC.

The Scientific Institute is the collection of astronomers who will be using the Telescope and provision will be made for guest astronomers to supplement the staff.

The relationship between GSFC and the Institute is a close one. While GSFC staff control the operation of the Telescope, the astronomer whose observations are being made will sit in to aid in target identification, and also to sample the 'quick look' data flowing from the Telescope to make sure that the best possible use is being made of the instrument in respect to the particular project. The bulk of the data is processed and formatted into the requirements of the investigating astronomer, whose property the data becomes. After a period of one year, it is expected that NASA will release the data from the archives for use by the scientific community at large.

The Space Telescope Scientific Institute also performs another vital function – planning. The Institute will select programmes from the scientific community and the astronomer whose programme is worthy of the Space Telescope will start planning the observations up to one year before the observations are due to start. The Institute will optimise the programme requirements, so that the observation is conducted at the most opportune time. The factors determining this will be avoidance of solar, lunar or terrestrial glare, and the operation of the Telescope at its highest efficiency; this will cause the minimal amount of movement to the Telescope as a whole, and the schedule of turning on and off various instruments. Calibration needs and communication requirements also will have to be taken into account.

The Space Telescope will be used in connection with the TDRSS (Tracking and Data Relay Satellite System) the first of which will be launched on the eighth Space Shuttle flight in 1980. The system will replace the existing ground-based tracking system operated by NASA.

It is anticipated that the down link data rate will be 2.8×10^9 bits per day, with a maximum of 3.7×10^9 bits per day. The fluctuations arise due to exposure time. A number of short exposures will generate more data transmission than a lengthy exposure. The maximum exposure is of course limited by orbital parameters and is unlikely to exceed 30 minutes.

The facilities, in part, already exist at GSFC for the International UV Explorer Programme, when 50 guest observers every year can be accommodated, and real-time target acquisition facilities are available. The Telemetry Operations Processing System at GSFC will handle data volumes several times greater than the anticipated Space Telescope load, and subsequent image processing of 2×10^{11} bits per day will be attainable.

Scientific Instruments

The Space Telescope has at its prime focus a collection of five Scientific Instruments (SI). Each is in a separate module of identical dimensions completely independent of the others so that any one can be removed without interference, or replaced with another of a more advanced design in the future. This modular arrangement also enables astron-

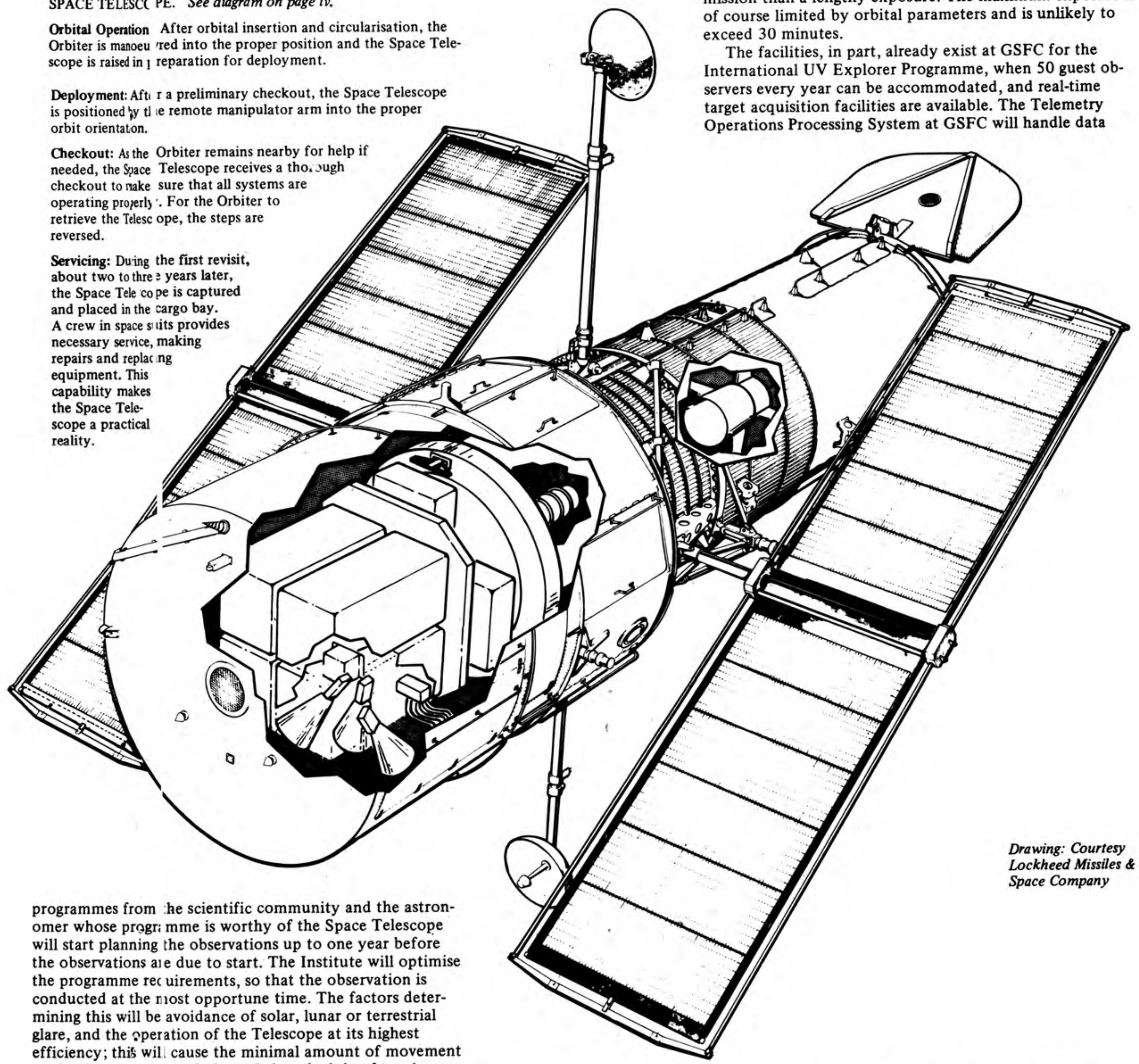
SPACE TELESCOPE. *See diagram on page iv.*

Orbital Operation After orbital insertion and circularisation, the Orbiter is manoeuvred into the proper position and the Space Telescope is raised in preparation for deployment.

Deployment: After a preliminary checkout, the Space Telescope is positioned by the remote manipulator arm into the proper orbit orientation.

Checkout: As the Orbiter remains nearby for help if needed, the Space Telescope receives a thorough checkout to make sure that all systems are operating properly. For the Orbiter to retrieve the Telescope, the steps are reversed.

Servicing: During the first revisit, about two to three years later, the Space Telescope is captured and placed in the cargo bay. A crew in space suits provides necessary service, making repairs and replacing equipment. This capability makes the Space Telescope a practical reality.



Drawing: Courtesy Lockheed Missiles & Space Company

omers of the future to establish different priorities for the type of instruments flown on the Space Telescope.

At this stage it is envisaged that the Space Telescope will have a lifetime of 15 years. After that time our technology may permit an even larger telescope in orbit or on the far side of the Moon, but undoubtedly astronomers will still be keen to use the 'old' Space Telescope. After all Mount Wilson Observatory did not become obsolete on the completion of Palomar!

The *f*/24 Field Camera

Perhaps the most fundamental instrument on the Space Telescope is the *f*/24 Field Camera which can be used by itself, or simultaneously with another instrument module. The heart of the camera is the SECO (Secondary Electron Conduction Orthicon) tube. Basically this is a television camera tube modified for low light applications and very high resolution. It is commonly known that the greater the number of scanning lines on a television picture the greater is the resolution of that picture. Domestic television systems use 625 lines per picture (525 in North America and Japan); by contrast the SECO tube to be used in the Space Telescope will have 2,000 scanning lines. The even number of lines is indicative of the long exposures required from this tube, rather than the 50 or 60 pictures per second we are used to for portraying movement on the domestic television screen. It is almost certain that the Westinghouse WX 32193 SECO tube will be used, the size of the optical image focussed upon its target plate being 50 mm (2 in.) square. The other facility on the field camera is a star calibration system.

The Faint Object Camera

An agreement was reached in 1974 by NASA and ESRO (later to become ESA) for European participation in the Space Telescope. The early options were for either a faint object spectrograph or the *f*/96 high resolution camera. In 1975, however, ESA agreed to drop the development of the spectrograph and renamed the camera the Faint Object Camera.

The feeble starlight is first focussed onto an electronic image intensifier whose output is scanned by a television camera tube. The signal from the camera is processed electronically to determine the x, y co-ordinates of the original photon. In this way the signal to noise ratio is preserved and some of the lost resolution from the amplifying stage is recovered. Finally a counter sums the number of photons appearing at each co-ordinate position.

ESA is currently evaluating a number of detector systems (or television camera tubes) for the camera. At first sight they could use a system developed by University College London, which is currently in use on ground based telescopes. It would require slight modifications to make it sensitive to vacuum ultra-violet, but a more serious problem is the power dissipation of the system, which at 350 watts is far too high for use on the Space Telescope. In eliminating the power problem designers are faced with a large size and mass.

An alternative approach is to use an intensified Electron Bombardment tube for detection. This does not give the same resolution as the previous choice, but is of a higher sensitivity, and therefore requires less gain in the image intensifier stage. Such a system has never been used in practice, but all the component parts have been proven and it would not be necessary to space-qualify the system as a whole.

There is yet a third alternative using a microchannel plate image intensifier, which might prove to be the most satisfactory solution, but as yet the technology to produce such a device is not sufficiently advanced. Although it cannot be used on the initial flight of the Space Telescope, it could be introduced at some time in the future.

The problem of data storage from the Faint Object Camera has yet to be resolved, but the European community, with its expertise in the Helios on-board computer, is in a good position to contribute either by up-rating the Helios-type processor, or hybridising that system with another system involving a shift register feeding into a main store.

Planetary Camera

In order to observe bright objects with a high magnification, a planetary camera will be used. A multiposition capping shutter will select one of two focal length systems of *f*/48 and *f*/96, the fields of view being 17 seconds of arc square for *f*/48 and 8 seconds of arc square for *f*/96. The former has a resolution of 0.1 seconds of arc while the latter is diffraction limited.

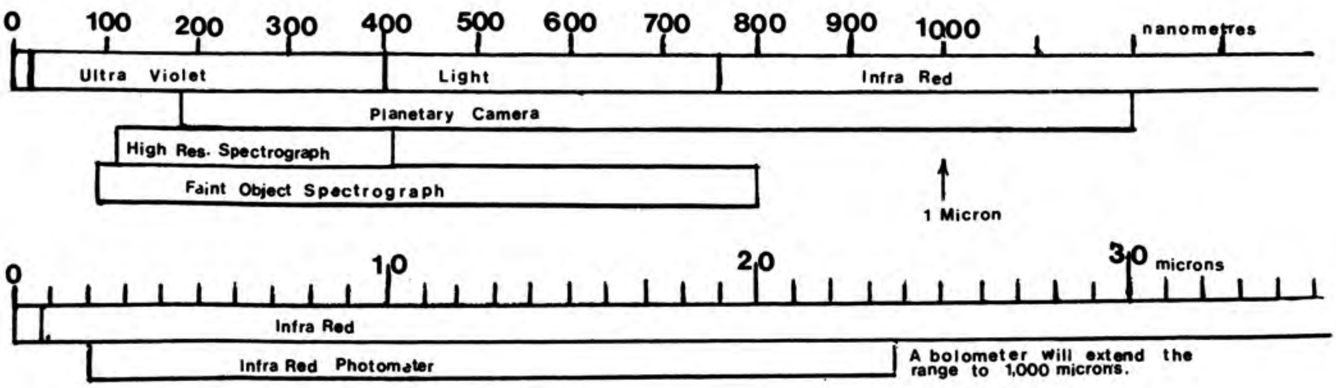
High Resolution Spectrograph

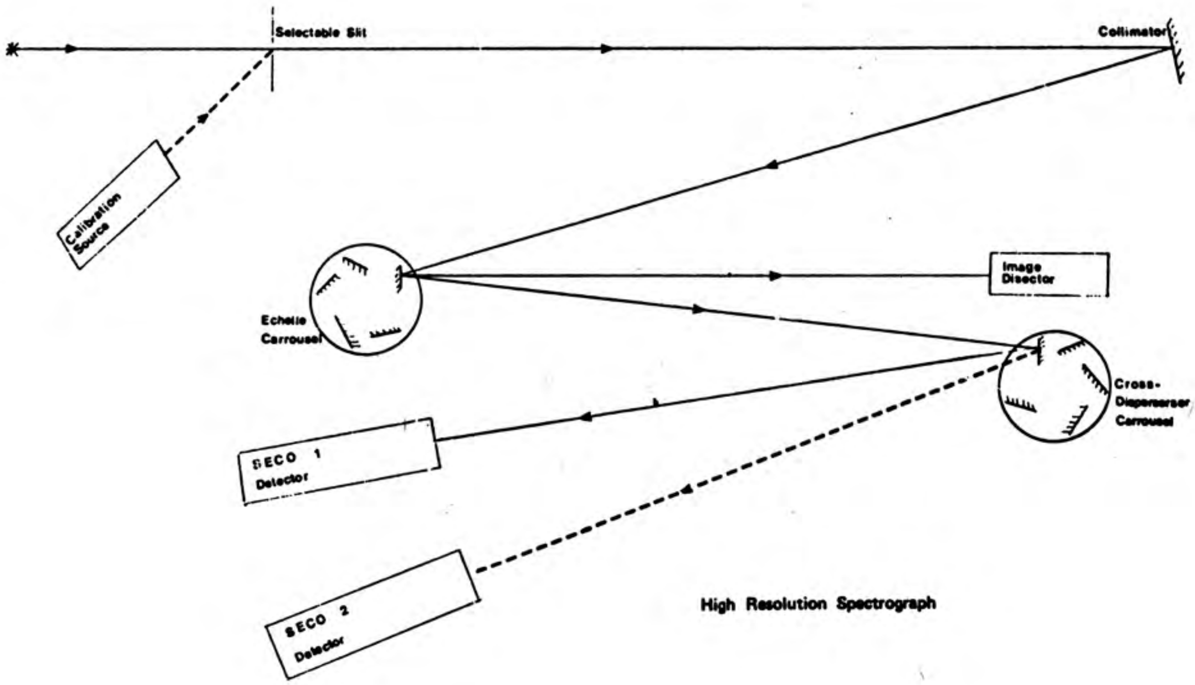
In order to analyse the light from celestial objects, the Space Telescope will carry a Spectrograph, covering the range from 115 to 410 nanometres. The instrument has two SECO tubes, one sensitive to the visible portion of the spectrum and the other to the infra red.

The module contains two carrousels on which are mounted a selection of gratings and mirrors, such that by a suitable combination of mirrors, gratings and SECO tubes the spectrum can be analysed at a variety of wavelengths and resolutions. There are a total of 11 modes of operation.

One of the carrousels has a sinusoidal rotation of ± 15 seconds of arc to offset the doppler shift caused by the Space Telescope's motion. Target acquisition and identification is performed by a small detector which takes a small

Spectral response of some Scientific Instruments on the Space Telescope.





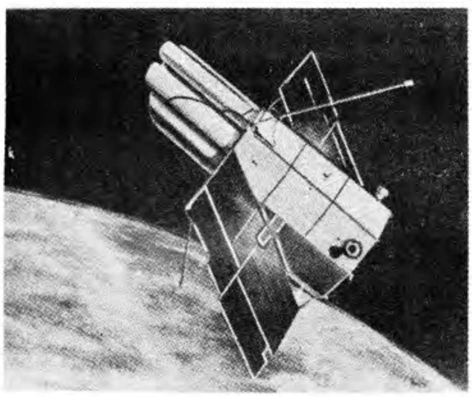
High Resolution Spectrograph

portion of the collimated beam from the first carrousel. Guidance control is linked to this detector through a servo loop. In addition an optical calibration signal can be fed into the spectrograph.

Faint Object Spectrograph

The main element in this module is the image splicer which compresses three times as much information onto the detector's image plate, and therefore permits more of the spectrum to be recorded.

Operating in its normal mode, this instrument will record the spectra of stars down to magnitude 21, roughly the limit of the Palomar telescope, but by operating in the collapsed dispersion mode, where resolution is reduced by a factor of 10 to enable more photons to fall on each picture element of the detector, magnitude 26 stars can be analysed.



COPERNICUS. Artist's impression of the Orbiting Astronomical Observatory (OAO-3) 'Copernicus' which gave Space Telescope designers valuable experience. The 2,220 kg satellite, built for NASA by Grumman Aerospace Corporation, is 3.05 m long x 2.15 m diameter. It was launched on 21 August 1972 into an orbit of 736 x 744 km inclined at 35.01 deg to the equator and is still supplying data on stellar and interstellar phenomena.

Alternatively, in the high-dispersion mode a resolution of 10 times greater than normal can be achieved permitting the observation of fine detail in the spectra.

The Infrared Photometer

Most of this instrument is enclosed in a 'Dewar Jar' (an overgrown Thermos Flask), and maintained at 2°K (-271°C) by means of liquid helium. Any increase in heat, by say the electronics, inside the jar, is taken away by the helium. The 'hot' helium is dispelled to space by a pair of opposed nozzles, set tangentially to the Space Telescope's skin so that no force (however minute) is applied to the telescope as a whole.

In order to reduce the thermal noise that the telescope 'sees' a mirror scans the inside of the Telescope as well as the aperture. The output from the instrument consists therefore of the object under observation plus background noise followed by pure noise. This cycle is repeated between 3 and 30 times per second, and later analysis will be able to remove the value of the noise from the data giving a clean observation of the stellar source.

High Speed Point/Area Photometer

This is the most sensitive of all the ultra-violet and visible instruments carried on the Space Telescope. It consists of two sets of filter wheels with eight positions on each wheel (including an open position on both) so that each filter can be used singularly, or in any combination.

It will reach stars down to magnitude 26.5 or better. In the original proposal polarisation detection was incorporated, and although this facility has been dropped, in can fairly easily be re-introduced into this instrument at a later date.

Astrometer

The design of this instrument has not yet been finalised, but it is hoped that it will be able to measure proper motions of stars 10 times more accurately than at present and to measure the angular diameters of stars and the nuclei of galaxies.

Of the instruments listed above ~~only~~ five will be located

The primary mirror blank is being manufactured at the Corning Glass Works, Canton, N.Y., under contract to Perkin-Elmer Corporation. The mirror is scheduled for delivery late this year. Then will come the laborious process of grinding and polishing the glass to its optical curvature.

in the Space Telescope at any one time. But because of the unique facility of refurbishment by the Space Shuttle, it is possible to build up an observing schedule over the next decade whereby all of the instruments will be used, and indeed many more added to the list.

The Mirror

Having reviewed the specification and the Scientific Instruments of the Space Telescope, it remains to review the programmes which will satisfy the astronomical and scientific community. The quest for knowledge in itself will be of benefit to Mankind, but of equal consequence is the advance in technology that is bound to result from industry responding to the challenge

The most obvious problem to be faced is how to build a mirror of 2.4 metres (94 in.) diameter suitable for a space application. There are many ground-based telescopes of greater size, but the Space Telescope is a particularly interesting prospect.

The process begins with Ultra Low Expansion Glass made at the Corning Glass Works by introducing a mixture of silicon tetrachloride and titanium tetrachloride into the flames of the burners [6]. Hot silica 'soot' particles fall from the overhead burners, and are collected over a period of weeks until they form a disc 1.5 metres (5 ft.) in diameter and 80 to 130 mm (3 to 5 in.) thick. Each disc is tested and used where appropriate in the mirror; for example the front plate of the mirror is made from glass that is selected for its ability to polish up well. It is a property of Corning's ULE glass that it can be welded together, so the mirror is fabricated from a number of discs.

The Structure

The structure has to remain rigid even though the Telescope might experience severe heating and cooling in the space environment. The tolerance is such that the primary and secondary mirrors, which are 4.9 metres (16 ft.) apart, must not move by the expansion of the support membranes by more than 1 micrometer (0.4 thou). Moreover, the working depth of focus at the $f/24$ image plane is only $\pm$ 0.4 millimetres (0.16 in.) at the average wavelength of the incident light.

In order to meet these stringent requirements, the majority of the Space Telescope and Scientific Instruments will be constructed from graphite epoxy which has an extremely low coefficient of expansion, and a very good strength-to-weight ratio.

Guidance Control

It is common practice in astronautics to orientate a spacecraft by detection of bright reference stars like Canopus, or Vega, but the problem that faces the Space Telescope is of locating very faint stars and holding them steady in the field of view. Often the reference star might be several seconds of arc away from the target star. The problem is compounded by the laws of nature which do not distribute the stars evenly throughout the sky. It is probable that astronomers will call upon the Space Telescope to be directed at right angles to the plane of the Milky Way, and by so doing encounter fewer stars for guidance control.

Another problem is introduced as soon as the Telescope is turned towards a planet. The very high resolving power of the Space Telescope results in the planet's motions against the star background becoming noticeable even during the brief period of the observation. The guidance therefore will have to be programmed to allow the Telescope to move in order to follow the motion of the planet. Moreover, the Telescope's own motion will also introduce parallax errors even greater than the pointing accuracy of the Telescope, and these too must be compensated for in the guidance system.

The Optical System

In order to operate the instrument at its optimum, stray light inside the Telescope tube must also be supressed. This is done by placing baffle-fins inside the blackened tube, but even this is more complicated than one might at first suspect since the baffle-fins themselves can introduce diffraction and reflections from their edges, but these are usually of minor importance.

The optical performance of the Telescope will be constantly monitored by three sensors placed at the edge of the field where astigmatism is greatest. Error signals generated by these sensors can then alter the position of the secondary mirror to remove most of the aberrations.

Acknowledgements

An article of this length can only outline the bearest details of the research that has gone into the planning of the Space Telescope. In preparing this account, the author wishes to acknowledge the 228 page Technical Report on the 21st annual meeting of the American Astronomical Society, held in Denver, Colorado, on 26-28 August 1975. This report, entitled 'The Space Telescope', is available from the Superintendent of Documents, Washington, D.C., at a cost of $2.30, or can be obtained on loan from the BIS Library, quoting reference NASA SP-392 in either case.

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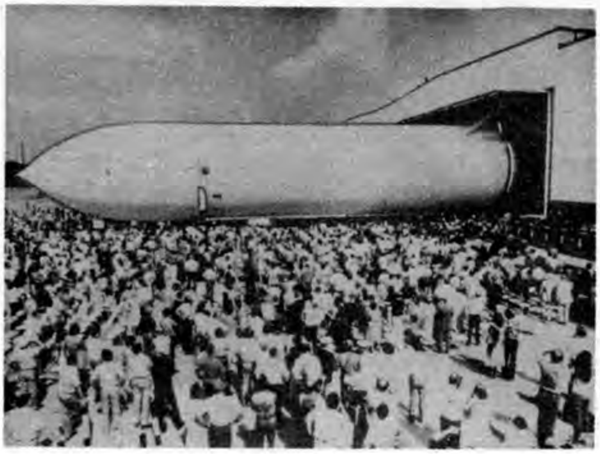


First Space Shuttle external tank is rolled off the assembly line at the Michoud Assembly Facility in New Orleans on 9 September 1977. This tank, a Main Propulsion Test Article (MPTA), was transported to the National Space Technology Laboratories in Southern Mississippi and installed in a test stand for use in static firings of the Shuttle's cluster of three main engines.

National Aeronautics and Space Administration

"The idea is to get as much training as possible for the crew," Urlaub said. "It avoids a dead-end training curve so you're not training people who won't be doing it later." Again, the tank will be filled with 70 tons of water and another six weeks of tests will begin, this time simulating liftoff.

Finally, they will be disassembled and reassembled, this time with empty boosters and 50 tons of water to simulate launch just before booster jettison.

Through it all, a special fleet of instrumentation trailers hooked to the Shuttle will record every bump and grind. Engineers will be able to analyze part of the data as the tests go on, rather than wait for weeks as they did with the Saturn V, and be able to make changes while the test is underway. Although it is a launch vibration test, the forces applied will be "well below any limlits established by the design," Urlaub said.

Data from MVGVT, earlier quarter-scale tests, wind tunnel runs, structural tests, and engine firings will be integrated into a final mathematical model of the Shuttle to determine its strengths and weaknesses.

By November, the last of the tests should be finished. In December, the 'Enterprise' will be flown back to Edwards, then returned to the Rockwell International facility at Palmdale.

There, the 'Enterprise' will be cannibalized. It's an inglorious fate for the ship named by Star Trek fans, but a budgetary necessity. The 'Enterprise' was built while the Shuttle design was being refined, and would require a new set of plans to lay out the plumbing, electronics, hydraulics, and secondary structures. It is also 8,000 lb. (3,628 kg) too heavy, and would not be able to carry a full 65,000 lb. (29,484 kg) payload.

The external tank will be refurbished and used on the seventh Shuttle launch.

COVER-UP AT KENNEDY

There's a cover-up going on at Kennedy Space Center, and the public affairs office admits they can do nothing about it. And the press is likely to agree, though grudgingly.

The cover-up involves modifications at Launch Complex 39A to accommodate the Space Shuttle, writes Dave Dooling. The rotating service structure (formerly payload changeout room) will stand directly between the Shuttle and the press site by the vehicle assembly building.

"That's a problem," said Hugh Harris, the chief of public information at Kennedy. "We've been worried about that ever since they told us they were building it. And there is no way of moving the press site because of the impact lines."

The press site is located at the turn basin used by barges bringing in oversized rocket stages. It is 3.1 miles west of LC-39A, and gave reporters and photographers an excellent view of the Apollo-Saturn V Moon launches and later of the Skylab launches. Harris said he tried to get the press site relocated, but there are no sites available within a reasonable distance.

Ed Harrison, who is in charge of photography arrangements at Kennedy, said photographers will still be able to put automatic cameras near the pad as they did for Apollo.

"I don't think the press site is going to be all bad, he said, "because of the width of the bird. And once it climbs it will really be visible."

One thing that should make the press happy is a permanent press building that will be erected behind the grandstand at the press site. This will give reporters and officials a convenient office and auditorium rather than using motels at office suites in Cocoa Beach (the current practice).

The building won't be fully opened, though, until after the first few launches and press attendance starts to dwindle.

WATER TANK FOR JOHNSON

Johnson Space Center will soon be getting its own underwater zero-g simulator despite the best efforts of Alabama congressmen to block it, writes Dave Dooling.

By reprogramming $860,000 in residual construction funds, JSC will be able to build the water immersion facility without a formal budget request going through the Congress. Rep. Ronnie Flippo and Rep. Walter Flowers of Alabama had blocked four previous requests on the grounds that it would duplicate the neutral bouyancy simulator at Marshall Space Flight Center in Huntsville.

The MSFC tank is 75 ft in diameter and 40 ft deep. The JSC tank will be 78 ft long, 30 ft wide, and 25 ft deep. One end will be a semicircle. It will be built in building 29, which once housed the flight acceleration facility, a centrifuge used by Gemini and Apollo astronauts. The centrifuge has been disassembled and the building prepared for construction of the water tank. The tank will be made of concrete and sunk 15 ft into the ground, unlike the aboveground steel tank at MSFC.

In late March, NASA formally notified the House Committee on Commerce, Science, and Transportation of its intent to reprogramme construction funds, including money already earmarked for JSC. A construction contract was to be awarded in June with completion due a year later.

An aide to Flippo has indicated that the congressman did oppose the reprogramming so as not to endanger other space projects he is supporting. Disapproval would have to come from the entire committee which is chaired by Olin Teague of Texas.

The water tank at MSFC has been used extensively to simulate work in zero-gravity. The physiological effects cannot be simulated, but it gives an accurate representation of the physical demands. During 1973-74, the MSFC tank was used extensively to work out repair procedures for the crippled Skylab space station.

The JSC tank will be used primarily to train Space Shuttle astronauts. Its size is large enough to allow work in and around a full-scale mockup of the Shuttle payload bay and flight deck, but not for the sort of large space structure work now under way at MSFC.

SOVIET/US ROCKET TESTS

A Soviet research ship arrived off the Virginia coast near NASA's Wallops Flight Center, Wallops Island, last June to participate in a series of rocket tests designed to investigate ionization sources in the upper atmosphere. Launches were conducted before, during and after a solar flare or intense magnetic storm.

Ionization is the process by which neutral atoms or groups of atoms become electrically charged, either positively or negatively, by the loss or gain of electrons. The objective of the Joint American-Soviet Particle Intercalibration (JASPIC) Project was to compare the techniques used by both countries over the years to deduce the intensity of energetic electrons and protons coming down into the lower ionosphere. The project was designed to gather experimental evidence concerning the role of these particles in creating ionization in the lower ionosphere at night at mid-latitudes.

The particles are thought to cause high latitude auroras, and sunlight is believed to be the principal source of ionization everywhere in the daytime.

The research ship, *Professor Vize,* operated offshore and served as the Soviet launch platform. Comparison tests were made on the basis of four sounding rocket launches from Wallops Island and five Soviet MF-12 rocket launches from the ship. One of the Wallops-launched rockets carried a chemical cloud release experiment which was plainly visible to East Coast residents.

A similar project involving US/USSR intercomparison of meteorological sounding rockets was conducted jointly last August from the Wallops Island range and the Soviet ship, *Akademik Korolev,* located offshore. In that project, 22 pairs of meteorological rockets were launched during a two-week period.

In the past there have been disparate instrument measurements of energetic particles in the ionosphere. At a meeting of the International Union of Geodesy and Geophysics in Grenoble, France, in 1975, US and Soviet scientists agreed that the first question to be resolved was instrument credibility. A joint measurement of the intensity of energetic electrons and protons at the same time and place is a first step in understanding the apparently conflicting results reported in the scientific literature.

'COSMONAUT PAVEL BELYAYEV'

A new Soviet Academy of Sciences research ship, the *Cosmonaut Pavel Belyayev*, recently completed its maiden voyage. The ship is equipped with a new device which, unlike her predecessors, keeps its main antenna constantly fixed on its orbiting target even in the roughest seas, writes Dave Shayler.

The new research vessel will conduct investigations of the upper layers of the Earth's atmosphere and of outer space. However, its prime function will be to receive signals from Soyuz spacecraft, whilst they are out of range of tracking stations on Soviet territory, and to transmit commands to them, acting as a relay between the crew in space and flight controllers on the ground.

The new ship joins the research vessels *Komarov, Gagarin* and *Volkov*,the *Belyayev* being of the same fleet as the *Volkov* which was launched last year (*Spaceflight,* December 1977, p. 439) and will be joined in the near future by the *Cosmonauts Georgi Dobrovsky* and *Viktor Patsayev.*

Pavel Ivanovich Belyayev, a Lt. Colonel in the Soviet Navy, was born on 26 June 1925, in the village of Chelishchevo, in the Vologoda Region, and in 1960 became a member of the very first Cosmonaut detachment. He was the first Commander of the detachment until the summer of 1961 when he sustained a broken ankle due to a parachute landing mishap. He returned to active flight status in the summer of 1962. His only space flight was as commander of Voskhod 2 18-19 March 1965, during which time the world's first space walk was undertaken by Alexei Leonov.

He was apparently closely connected with the Soviet manned lunar programme during the late 1960's. He may also have been one of the prime candidates for commanding the first Soviet circumlunar mission (around late 1968 – early 1969) before it was permanently abandoned in early 1969.

Belyayev, the 10th Russian to fly in space, a Hero of the Soviet Union, died on 10 January 1970 as a result of complications following an operation for stomach ulcers. He was married and had two children. A member of the Soviet Communist Party, he was a poet and a painter. Belyayev had logged a total of 26 hours and 2 minutes in space. In his honour the Russians posthumously gave his name to a far side lunar crater.

SPACE PICTURES

A new album, *Man and the Universe*, has been published by Izobrazitelnoye Iskusstvo Publishing House in Moscow. It contains paintings and sketches by cosmonaut Alexei Leonov and artist Andrei Sokolov.

Included are sketches made by Leonov in his log during the Soyuz 19 mission. Other paintings portray episodes in the history of space flight.

VANDENBERG AND THE SHUTTLE

The U.S. Air Force may be left out of the Space Shuttle programme if Congress accepts cuts proposed by the General Accounting Office, writes Dave Dooling. GAO, in its annual review of the Shuttle programme, says that three Shuttle Orbiters and one launch facility are sufficient to handle all civilian and military space operations.

This is "totally unacceptable" to Dr. William Perry, undersecretary of defense for research and engineering, and "irresponsible" to Dr. Robert Frosch, NASA administrator.

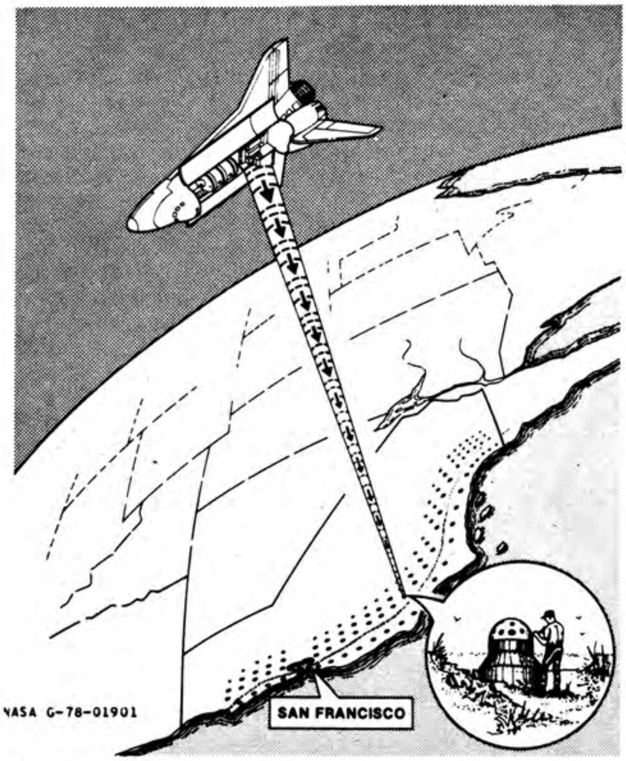
GAO is proposing that Vandenberg AFB's Space Launch Complex 6 (SLC-6) not be modified to handle the Shuttle's polar launch needs, and that the fourth Orbiter be dropped (NASA and the Air Force wanted five, but the FY 79 budget proposal dropped it).

The cutback, if adopted, would require overland launches from Kennedy to reach polar orbit. Kennedy is normally envisaged for 28.5 to 57 degree inclinations, and Vandenberg for 56 to 104 degrees. But GAO claims that there will not be enough traffic to justify SLC-6 and the fourth Orbiter, and that polar orbits can be reached from Kennedy.

Technically speaking, polar orbits can be reached from Kennedy, but only by flying over the southeastern United States. The 90-ton casings of the solid rocket boosters would parachute into South Carolina, and both boosters and external tank would fall on the U.S. or Canada in case of a launch abort.

Perry predicted it would take until the end of the century to complete the environmental impact statements for such flights.

Frosch said that GAO assumptions of Shuttle safety



A new laser ranging system is under study for use aboard the Space Shuttle to monitor strain build-up in the Earth's crust. Such strain is thought to be an early indicator of earthquakes in the making. Initial tests of the system may be made as early as 1982 of the quake-prone San Andreas Fault in southern California. System is based on use of the Shuttle-borne laser to locate a number of optical reflectors. This reflector network will cover an area 200 km along the fault by 400 km inland. Any change in the location of the reflectors from mission to mission will be due to movement in the Earth's crust.

National Aeronautics and Space Administration

(because of its man-rating) are based on old data and that the chances of injury are 1 in 166. "I'm afraid that I must characterize the suggestion as irresponsible," he said of GAO's proposal.

The strongest objection, though, is international. The Shuttle coming over the North Pole could appear to the Soviet Union as a ballistic missile attack. "No matter how sophisticated the Soviet radars, the similarity of such northerly Shuttle launches to potential U.S. ICBM launches can lead to adverse Soviet reactions, if done routinely," Perry said. "Under worst-case conditions, such as the Shuttle breaking during ascent, a severe Soviet response cannot be discounted."

The debate was a continuation of the GAO-NASA battle that started with the inception of the Shuttle. "They've been very negative in their attitude over the past years.... about making costs, making schedules, two launch sites," said Joaquin A Saavedra of the Shuttle development office. "This year they're ignoring development and concentrating on Vandenberg Air Force Base."

Saavedra said GAO has proposed "tremendous changes" in the Shuttle design to improve its polar performance out of Kennedy, especially if it uses a fuel-consuming dogleg that would reduce its flight over land. He said GAO's stance was very discouraging because it was using the work of a single expert to say that hundreds of NASA and Air Force engineers had miscalculated.

The debate came during Congressional testimony in March.

ROLES OF COSMOS SATELLITES

A few more facts about the operation of Soviet scientific satellites have been given in an article commemorating the 1,000th satellite of the Cosmos series (*Aviatsiya i Kosmonavtika*, May 1978).

The authors G. Narimanov (Lenin Prize Winner, Doctor of Physical and Mathematical Science) and B. Pokrovsky, engineer and 'honoured radio operator,' first recall that the programme began on 16 March 1962 when the two-stage Cosmos-RN rakata-nositel (carrier-rocket) was introduced for the launching of a large number of scientific satellites. Some Cosmos satellites reported their findings according to the program of an onboard computer; others had to be commanded to do so from ground stations and new instructions were also fed in. Where there are no ground stations in any particular part of the USSR, special aircraft are flown; they can receive data when they are airborne or on the ground.

The following satellites were active in specific roles:

Cosmos 381 was an ionospheric sonde. Cosmos 261 was a winter ionospheric research project; 348 was a summer ionospheric project.

Cosmos 26, 49 and 90 investigated the Earth's magnetic field; Cosmos 215 carried eight telescopes; Cosmos 243 had thermal radiation equipment and mapped Antarctica and the humidity and temperature of the Pacific Ocean.

Cosmos 92, 94 and 109 carried biological experiments including aquatic plants, plants and seeds.

Cosmos 110, 782 and 936 carried dogs and other animals.

Cosmos 186, 188, 212 and 213 tested spacecraft docking equipment.

Cosmos 97 tested a 'quantum generator.'

Cosmos 140 and 213 were used for 'superconductor' tests.

Cosmos 41 was the initial experiment leading to the Molniya series of communications satellites.

Cosmos 23, 122, 144, 156, 184, 206 were early weather satellites.

The 1,000th Cosmos satellite launched on 31 March 1978 was a navigation satellite.

ZELENCHUK TELESCOPE

Photographs obtained by the 6 metre optical telescope in the foothills of the Caucasus show that there are "three to four times more faint galaxies in the sky than stars." Thirty new Seyfert galaxies, where explosions are taking place involving matter billions of times greater than the mass of the Sun, also were discovered by the telescope which went into operation in December 1975.

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THE DEBATE ON SETI IN THE SOVIET UNION

By Boris Belitsky

Introduction

A fascinating debate has developed in the Soviet Union over the problem of SETI – the search for extraterrestrial intelligence. The leading and highly articulate spokesman for the majority view – namely, that this search is of tremendous importance to mankind – is Dr. Nikolai Kardashov, some of whose work in this field was reported in an earlier article [1]. The minority view – that there is actually no evidence to support the existence of any civilisations other than our own – is advocated by Kardashov's mentor, the eminent radio astronomer Dr. Iosif Shklovsky. What makes this scientific confrontation something of a paradox is the fact that Shklovsky was one of the pioneers of SETI research and co-authored with Carl Sagan that SETI classic *Intelligent Life in the Universe* [2], in which they presented a strong case for conducting a search for extraterrestrial intelligence.

Now – as, perhaps, befits youth – it is Kardashov who is vigorously carrying this quest forward (his endeavours, no doubt, facilitated by his recent appointment as deputy head of the Soviet Academy's Institute of Space Research), whereas Shklovsky has assumed the role of a questioning sceptic.

Basis of SETI

In his latest paper [3], Kardashov strongly objects to interpreting the negative SETI results to date as in any way making a positive outcome of the search unlikely. In fact, he sees SETI work up to now as having been largely of methodological value only. This is true, he feels, even of the most ambitious SETI experimental effort to date, Project Ozma II, carried out at the National Radio Astronomy Observatory in Green Bank, West Virginia, by Dr. Benjamin Zuckerman and Dr. Patrick Palmer [4]. For although this effort involved observing approximately 700 stars at the 21 cm hydrogen line radio wavelength, the observations of each star lasted for only a few minutes. The probability is negligible, he concludes, that the planetary system under study would have beamed signals in the direction of the Earth at just the right time for them to have reached us during those brief minutes.

Unlike Shklovsky, who takes the opposite view, Kardashov sees recent astrophysical findings as auguring well for SETI. Most important among these findings, he believes, is the extensive evidence that the forms of matter are the same over distance of thousands of millions of light years and over a time scale of thousands of million of years. In this space there have been found to be more than 10,000 million galaxies, each numbering more than 10,000 million stellar systems. Kardashov sees no reason why many of these stars should not have planetary systems like our own.

This is an important point of controversy in the SETI debate. Shklovsky has pointed to the growing number of stars that have been found to belong to binary, or multiple, systems, in which, he maintains, there is little likelihood of life developing because of wide-ranging temperature fluctuations [5]. But Kardashov espouses the view that multiple star systems can also have habitable planets. For example, when the components of a double star system are close to each other, a habitable planet could be in a near-circular distant orbit. If, conversely, the two stars are far apart, there could be a habitable planet in the near-circular orbit around either of them.

In Kardashov's view, the recent discovery of very narrow rings around Uranus lends additional support to the theory of planetary formation through the condensation of the planetary medium and, hence, to the multiplicity of planetary systems in the Universe. Together with the satellites of Uranus, the rings appear to form a planetary system in miniature. This is in good agreement with the condensation theory, which treats such rings as satellites that have not yet condensed. These satellites-in-the-making are thus assuming shape before our eyes.

Whereas Shklovsky dismisses as an "instrumental error" Professor Van de Kamp's claim to having established by stellar deflection that Barnard's Star has two planetary companions, Kardashov accepts both this claim and the more recent ones for planetary companions around Epsilon Eridani and Cin 18,2354.

Another recent astrophysical advance that Kardashov sees as justifying SETI optimism is the discovery of complicated organic molecules, the "building blocks of life," out in space. He concludes from this that there is plenty of initial material for the generation of life throughout the Universe.

Kardashov points out that whereas our Solar System is "only" about 5,000 million years old, other objects in the Universe can be as much as 20,000 million years old. Other civilisations can therefore be much older than ours and much more knowledgeable. Their knowledge, however, must certainly contain ours as a component, our knowledge evidently being an essential stage in the initial development of any civilisation.

In general, Kardashov views development as primarily implying the continuous absorption of new information. To illustrate how vast is the scope for adding to our knowledge, he lists some of the fundamental scientific problems still awaiting solution, among them a unified theory of gravitation and relativistic quantum mechanics, a theory of elementary particles, a theory accounting for the numerical values of the fundamental physical constants, and a theory of what preceded the observed expansion of the Universe and how it began.

Supercivilisations

From this he concludes that the knowledge built up by older civilisations should enable them to apply laws still unknown to us. This brings us to another point in dispute between Shklovsky and Kardashov. Shklovsky wonders why, if such a "supercivilisation" really exists, the "shock wave" of its intelligence has not spread throughout the Universe. But Kardashov counters this by pointing out that expansion in space may be of no interest to such an advanced civilisation. Everything in the Universe being the same, why expand? Moreover, increasing a system's dimensions is disadvantageous in terms of the speed at which information can be exchanged between its parts. Indeed, he argues, two civilisations that are far apart may even find it to their advantage to merge – this would increase the amount of information at the command of each, but the number of civilisations and the space they occupy would even diminish!

Instead of expanding in space, a "supercivilisation," in Kardashov's opinion, could well opt for very different avenues of exploration to learn about new fundamental laws. For example, it could choose to study the microworld, or conduct purposeful space flights to selected objects of interest in the Universe, or even explore the possibility of passing into other dimensions, say, through a rotating black hole....

It is this line of reasoning that led Kardashov to advocate a SETI strategy fundamentally different from that favoured by most Western scientists. He rejects the strategy of searching for civilisations like our own, i.e., associated with a planetary system and employing communication techniques

similar to our own. Instead, his strategy, described at some length in a previous article [1], involves searching for super-civilisations, which ought to command transmitters far more powerful than ours and could be engaged in advanced forms of astro-engineering activity detectable even over cosmic distances through thermal (black body) radiation. Such a strategy requires studying the most powerful (and often the most remote) sources in the Universe first and passing on to the fainter ones only when the signals from the more powerful sources have been proved to be of natural origin.

Kardashov is particularly interested at present in the search for new objects in space, especially by monitoring the lesser explored part of the electromagnetic spectrum, and in the study of galactic nuclei and quasars.

Kardashov's "Working Hypothesis"

For his guidelines he has adopted two working hypotheses. One assumes that the galactic nuclei and quasars are themselves associated with the activities of civilisations. According to the other, the civilisations make use of the enormous radiation from these sources just as we use the energy of the Sun. In the latter case the astro-engineering activity would probably be at some safe distance from such powerful sources. Or else, the density of matter in such objects being low, the engineering could well be conducted in their interior. Astrophysically speaking, both galactic nuclei and quasars belong to the "first generation" of objects in the Universe, which makes them roughly four times older than our Solar System. By extrapolating the growth of our energy production over such a time span, Kardashov finds that it could well reach quasar level at that point of development....

In our own Galaxy Kardashov is, accordingly, interested most of all in the phenomena taking place in the oldest stars (which are subdwarfs 5 to 15 thousand million years older than our Solar System) and in the nuclei. He sees the best chance of detecting either informative signals or the thermal radiation due to astro-engineering not in the "water hole" region favoured by American experts (i.e., the region between the emission lines of hydrogen and of the hydroxyl radical, the two components of water), but in the millimetre range and, specifically, at 1.7 mm. He has arrived at this conclusion by taking into account the cosmic background radiation and its peak.

Kardashov hopes that a SETI effort in this part of the spectrum will either link known astronomical objects with the activity of civilisations or lead to the discovery of an entirely new class of such sources. It is in this context that he is interested in a point radio source (smaller than our Solar System) responsible for a short-wave emission from the very centre of our Galaxy and in several infrared sources nearby, whose temperatures appear to be close to room temperature. He is undismayed by the discovery of a rather intense X-ray emission from that area since the beginning of 1975, since we must not discount the possibility of what he describes as "technologies and safety engineering quite beyond our present comprehension."

This approach has led Kardashov to challenge Shklovsky's famous "presumption of naturalness," i.e., the principle that every source must be presumed natural until proved artificial. Kardashov emphatically rejects this principle and argues that since either presumption (of natural or artificial origin) can generate rational experiments, every scientist must be free to work within a frame of reference determined by his set of notions and intuition. The "presumption of naturalness," on the other hand, would impose unnecessary and, indeed, harmful constraints upon a scientist's options.

Future Research Programmes

Finally, let me add that Kardashov's interest in all these problems is by no means purely theoretical. He expects a great deal from the use of the Very Long Baseline Interferometer technique, with the interferometer components spaced farther apart than the diameter of the Earth, and from the use of spaceborne radio telescopes generally. A suitable SETI effort employing such techniques, he believes, could even produce positive results within a decade, and this would make available to mankind the vast store of information accumulated in the Universe over thousands of millions of years.

I would not expect the continuing SETI debate in the Soviet Union to impose any severe constraints upon reasonably justified scientific programmes.

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FUTURE LUNA PLANS

By the end of this present decade a Soviet unmanned Luna type spacecraft should return to Earth rock and soil samples of the lunar far side. Hitherto all landings on the Moon both manned and unmanned have been targeted for the near side, because of the ease of communications between the spacecraft and with the Command Centre on Earth. Since the first spacecraft was put into orbit in 1966 (Luna 10) valuable information on the far side has been obtained by Luna and Zond probes of the USSR and Lunar Orbiter probes and Apollo astronauts from the US.

There has been a growing desire on the part of geologists all over the world to examine lunar far side material and compare their findings with results gathered from extensive examinations of returned Apollo and lunar samples of the near side. The next 18 months should see an expanded unmanned scientific programme by the Soviet Union to obtain such samples.

Such a mission would depend on a relay station in orbit around the Moon. For some time the Soviets have expressed interest in a polar orbiting lunar craft and improved orbital probes designed to produce geo-chemical maps of the whole lunar surface, and a complete and accurate photographic atlas of the Moon by 1983.

The Soviets must have been greatly encouraged by the news that NASA had been forced to drop plans for a similar mission due to lack of funds. Although Japan has expressed serious interest in sending unmanned spacecraft to the Moon in a future programme, the Soviet Union is expected to conduct the major share of lunar exploration in the foreseeable future, combining the joint activities of unmanned orbiters, sample return vehicles and Lunokhod roving vehicles, with eventually excursions into lunar orbit and onto the surface by Soviet cosmonauts.

NOVEMBER ISSUE

Charles A Cross explains the task of mapping the surface of the planet Mercury. We continue our series "Missions to Salyut 6" and examine the simulators being used for training Space Shuttle astronauts.

COMMUNICATION BETWEEN INTELLIGENT BEINGS

By Anthony T. Lawton and Penny Wright

Introduction

Ever since Man began to understand the real physical relationships between the Sun, Earth and other planets, and how they fitted into the Cosmos, he has pondered on the question: "Are we alone?"

Partial answers in biology and astrophysics have said; "No – we have counterparts elsewhere!" Recent advances in communication technology have given Man the means to say "Hello!" But the language and fashion in which he may speak is wide open to speculation. This paper shows that in communicating with others we may learn much about ourselves, for a particular message may have more than one meaning.

The Communication Syndrome

In bygone days Man believed firmly in 'The Harmony of the Heavens' and many poets, composers and philosophers outlined or wrote their ideas on The Music of the Spheres. Indirectly, they were expressing the collective ideas of mankind and desire to *communicate* with the Universe. For this reason we should remember that present ideas may appear just as quaint to our descendants 500 to 1000 years hence.

With improving astronomical and technical knowledge, communication ideas took on other guises. In the 19th century Karl Friedrich Gauss suggested the display of large geometrical patterns of sufficient dimensions to be seen by the telescopes of other beings presumed to inhabit the Solar System. Principal interest lay in the planets Venus and Mars. It explained the theorems of Pythagoras and consisted of circles, triangles and squares assembled to form a characteristic pattern (Fig. 1). The pattern was emphasised in contrast by choosing crops with differing colours or shades.

In this idea we have the basic elements of a communication system.

(a) It is unmistakeably the artifact of a reasoning intelligence for no degree of randomness would produce such an ordered outline.

(b) It has something to say and that 'something' contains specific logic.

These two requirements and nothing else form a communication information basis no matter how sophisticated the system may be. Any further material is either an extension of the logic, or guides and hints as to how the signal may be understood.

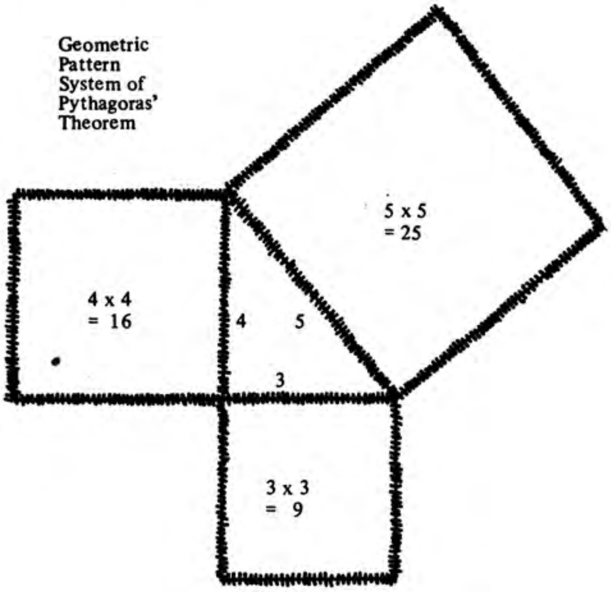
With hindsight and good photography of Earth from space, we now know this idea to have been impractical even though the dimensions suggested were large and the geometry to us appeared perfectly logical.

This signalling has several disadvantages. First, the cloud coverage of Earth, and water vapour content of the atmosphere reduce the contrast between differing surfaces. Of the thousand of photographs taken from space only a few show harvest patterns – and these are of some of the largest areas in the Canadian prairie.

This signalling system would be at an extremely slow rate and reach its peak amplitude for only a short section of the total signal time. A crop may take six months to grow and ripen, but its peak growth rate and hence contrast with background is less than three months, and with Gauss's original plan – a large area of forest – the 'signalling rate' would have been worse; a message would have taken years to form. The geometric pattern idea submitted by Joseph Johann von Littrow was not much better.

When we redicule now at these seeming simple ideas we should remember that both Gauss and Littrow were highly respected scientists of their time, one a mathematician, the other an astronomer.

Geometric Pattern System of Pythagoras' Theorem



Sides 3;4; 5
Squares 9;16;25
Sum 9+16=25
Gauss' proposal circa 1820

Fig. 1. The earliest proposal for signalling the presence of intelligent life on Earth. It was hoped that these patterns were large enough to be seen and understood by possible 'Martians'.

In 1863, Maxwell's theorems unified light and magnetism and gave birth to the discovery of radio waves. Maxwell died in 1873 but shortly afterwards Hertz, and later in 1899, Tesla (experimenting with a 200 ft. tower and very high voltage equipment) observed 'electrical actions' which he later reported as signals which to his mind were under intelligent control and yet (in his opinion) did not originate from his equipment. Neither did he attribute them to natural causes, e.g., the Sun or aurorae. However, today we would suspect such signals to have been generated by delaying and amplifying action within the ionosphere [1].

We are still in the "Radio Age" and if we widen our ideas to cover the whole of "Maxwell's Rainbow" we can say that 1863 heralded the "Electromagnetic Spectrum Age".

Late developments have centred on natural or logical resonant frequencies of common materials in the Universe – hydrogen, hydroxyl (water radicals) or some of the commoner carbon, hydrogen alcohols. The contemporary favourite is the "water hole", (Fig. 2) a space lying between the 1420 Mhz (21 cm) line of hydrogen and the two lines of the OH radical 1660 Mhz (18.0 cm) and the centre of mass of the water molecule at 1652 Mhz (18.15 cm). Project 'Cyclops' [2] describes the resultant 200 Mhz band in detail. In a later part of the discussion Cyclops asks for "International Protection of the Water Hole" in much the same manner as the hydrogen line is presently "protected" although it is almost impossible to prevent stray radiation being produced as leakage from generating some other radio frequency.

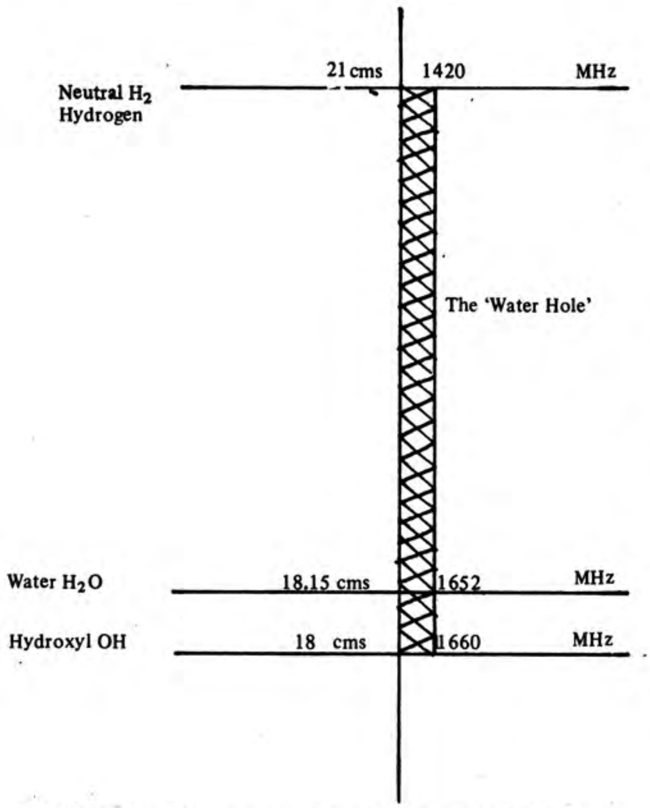


Fig. 2. The principal radio frequencies associated with the 'water hole'.

This problem multiplies rapidly if one contemplates generating the colossal RF powers suggested by Oliver *et al* [2]. These powers and the efficiency of any likely generating system means that such a beacon may absorb 10^{-12} of the *total* power emitted by the Sun. For this reason, we examined alternate CETI systems which avoided both this problem and that of what we termed "RF spectrum pollution".

In Ref. 3 we studied the possibilities of, and problems associated with, making the Sun a signalling system and suggested methods of making the Sun generate coherent light in discrete parts of its spectrum (Figs. 3 and 4).

The use of lasers as a method of signalling over interstellar distances is not new, having been first suggested in 1961 [4]. Nor is the use of spectral anomalies original, having first been suggested by seeding a G type star with technetium (Drake, *et al*) [5]. However, we do consider that by use of 'future technology' we may generate spectrally anomalous absorption lines in the Sun's normal radiation. The power levels are high – but the sobering thought is that these required power levels are already being generated in laser apparatus on Earth now. Although contemporary equipment produces very short pulses – the power generation in shortly-to-be-commissioned equipment is 20 to 200 Terrawatts, (i.e., a million Megawatts) or 1/500th of the total power output of the Sun!

This is not all, for present technology has also evolved items such as mirrors and modulators which handle coherent light power of these magnitudes in a highly efficient manner.

Within the next 100 years a system (or systems) may be set up which will produce signals of unmistakeable artificial origin in the spectrum of our Sun. Why then go to the trouble of generating RF power when the Sun does it "for free".

On a simple and very basic physics level, far greater power levels are generated by electrically excited plasmas than will ever be produced in mechanically dimensioned

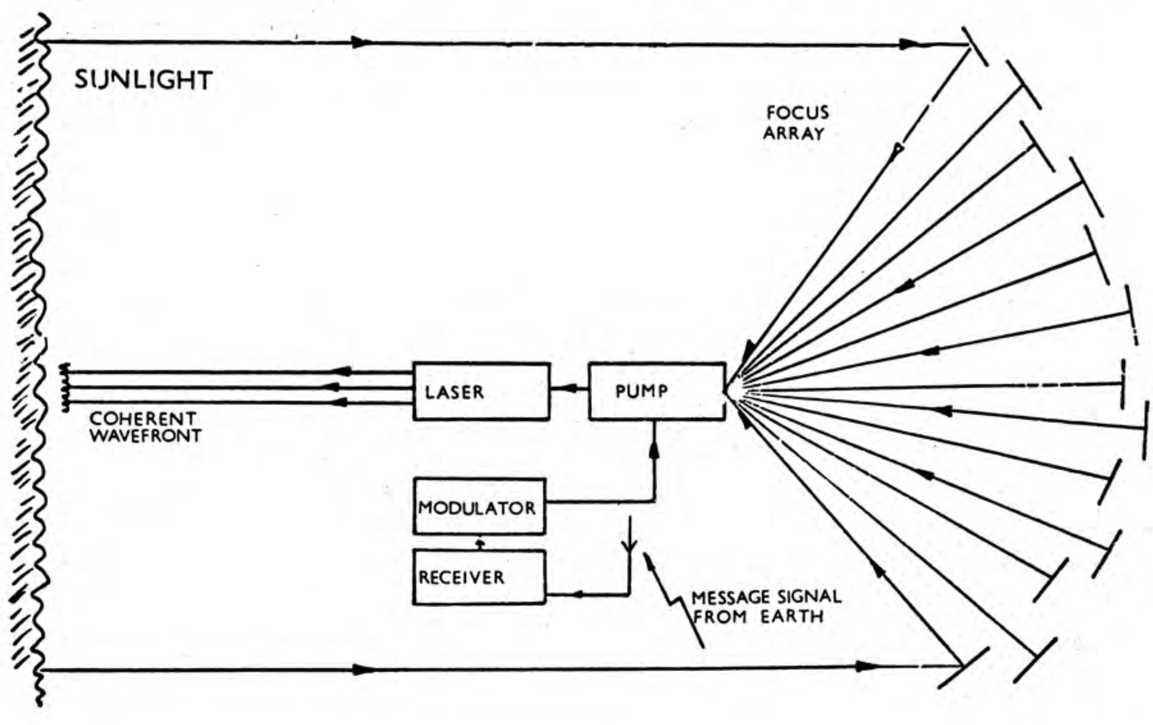


Fig. 3. Schematic of 'Solis' (Solar Origin Laser Interstellar Signal), a system for generating intense laser signals and producing an anomalous stellar spectrum. The laser is 'pumped' by sunlight collected and focused by a suitable reflector.

tuned cavities. Nature learned (or taught) that lesson the instant our Universe was born!

The system we propose does not produce high data rates – but that is unnecessary when signalling on a time band of several years. X-rays are the latest in Maxwell's Rainbow to be considered. The discovery of X-ray binary stars and X-ray supernovae or "bursters" have shown that signals need not be confined to the visible or radio parts of the spectrum [7]. At present we do not know precisely how these enormous energies are generated (10^{30} ergs/hr.) or why the mechanism should produce such regular pulses, but the very magnitude, detection range, and frequency of occurrence does suggest that other intelligent beings may consider them as a possible message carrier. The energy level corresponds to 2.7×10^{19} w^{-1} or 0.07% of the Sun's total energy.

There are other systems which rely indirectly on Maxwell's "Rainbow"; we have already mentioned a crude variant (Geometric Patterns). The latest – High Energy Particle modulation – shares a common factor with its predecessor in that it does not directly modulate the electromagnetic spectrum. In this category lie such systems as Bracewell Probes, genetic codes in carbonaceous chondrites and also the "Directed Panspermia" of Orgeul and Crick [6]. All of these direct and indirect systems are summarised in Table 1. There are gaps in the dates and the whole table only spans approximately 150 years.

We called this section "The Communication Syndrome" simply because advocates of a particular system base their ideas on a recent discovery or technological advance, and have rationalised the rest of the concept to suit.

Present schemes are soundly based when dealing with some form of electromagnetic radiation, but the final means used when communication *is* achieved may bear no resemblance to any system mentioned here!

Table 1. Methods of Signalling throughout the Ages.

Date	Indirect Method	Direct
Circa 1820	Geometric Patterns	–
1899	–	Radio Waves
1960	1. Bracewell Probes	Spectral Absorption Radio Waves (Masers)
	2. Reradiated energy at 10 microns by enclosing the parent star and planet by a shell made from dismembered planets.	–
1961	–	Light signalling (Lasers)
1962	1. Messages contained in carbonaceous chondrites	–
	2. Sun signalling, using cloud particles.	
1971	–	Infra-Red signalling
1973	Use of Neutrinos	
1974	*Pan Spermia* – genes in message form packed in spheres and scattered throughout the Universe.	–
1976	–	1. Ultra Violet signalling
		2. X-ray signalling
1977	HEPS (High Energy Particles)	'Solis' (use of the Sun to act as a Laser)

Manufacturing Messages

A message has three basic components:-

(a) Objective content.

(b) Subjective content.

(c) Redundancy.

Item (c) may seem strange to those conditioned to machine language. This on first examination seems to be *all* objective content. However, if one realises that "Start of Message", "End of Line" and "End of Message" components are not "message" but nevertheless essential, then these items are correctly classed as 'redundant'!

In ordinary language, spacing is essential as shown in the example (Fig. 5). If the spaces are deleted the message is nonsense. If the spaces are inserted then 30% of the total content of the message is used in redundant punctuation.

As an illustration, Fig. 6 is a simple digital coded Interstellar Message composed of 48 characters broken into 20

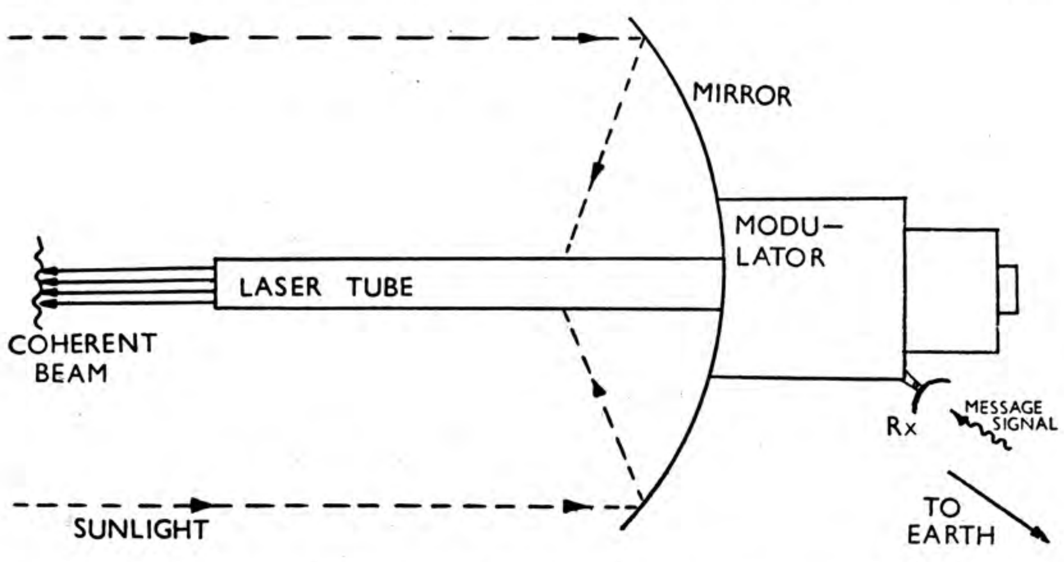


Fig. 4. Schematic of orbital 'Solis' showing basic elements of laser, collector, and modulator. For a power output of 10^{13} watts and placement at Mercurian orbital radius, the collector has a diameter of 85 km.

THATTHATISISTHATTHATISNOTISNOTISNOTTHATIT
37 Bits – All 'Ones' No Redundancy
Message Not Clear

THAT-THAT-IS-IS-THAT-THAT-IS-NOT-IS-NOT-IS-NOT--THAT-IT
52 Bits – 37 'Ones' - 15 'Zeros'
Message Clear

Fig. 5. Redundancy is essential in any message. This text is reproduced without redundancy in the first paragraph and is difficult to read. By adding redundancy – 15 spacings – the message is made clear. 15 zeros in 52 bits represents 38% redundancy – a typical figure for most languages.

"ones" and 28 "zeros". Of the latter, four zeros define the beginning of the message, two sets of three space the objective content, and the last set of six defines the end of message. The total is therefore 4 + 3 + 3 + 6, i.e., 16 'zeros' of redundancy. If we remember that the total content is 48 characters then 16/48 or 33% of the message is essential redundancy. Those who wish to persue this further will find that assessing the number of spaces in any phonetic language will give a redundancy of 30% to 50% as the established norm. Even picture languages such as the Chinese Kanji, or Egyptian Hieroglyph must have redundancy – the picture signs need spacing in columns and rows. Redundancy here was a matter of skill on behalf of the composer. The most common spacing is half a character width between individual characters in a row, and one character space between rows. Thus individual rows have 30% redundancy and a complete page has more.

Although our "message" is written in binary format (two states "0" and "1") we have deliberately used a simple code, widely known on Earth. (For those who wish to know the answer it is printed at the end of the paper).

This use of a known code highlights another facet of Interstellar Communication which is taken for granted, i.e., the logic used is so obvious that "everybody" – meaning all sentient beings who have received the signal – will understand it. In fact, this is unlikely as the example of our simple "message" illustrates. Some people looking at it will decode it straight away, others will need time to ponder and rewrite it in different format before solving it. Others still may need code instructions as to the cipher used – and some will not understand it at all.

Receiving and Understanding a Message

A similar fate awaits the signal sent to Messier 13 by Arecibo in November 1974. Each star of the 100,000 or so which make up the cluster will be equally irradiated and with antennae pointed in the right direction at the correct time will notice a rise in the received signal strength. But whether that is eventually recognised as artificial is another matter. If the receiver has a long smoothing time constant, the 'alien pen recorder' will merely chart the signal as a radio hot spot, and sweep on in its survey! The signal lasted three minutes. So what! The most likely explanation from the alien viewpoint would be that they had observed the radio outburst of a supernova – admittedly slightly long but not exceptional. Since most of *our* radio telescopes do not automatically go in for wide frequency band panoramic sweeping on sky surveys, on receiving such a signal we would not recognise its narrow band coherence and would probably pass it off as noise generated naturally.

If we assume a slightly different attitude among some inhabitants of M13 then they will have large antennae, low noise receivers with short time constants and some method of taking a reasonably wide band permanent record. This can be replayed at will and will be recognised as the work of intelligence.

This may represent the best that can be done and most in Messier 13 would stop there. Optimistically some might carry on – and note that there are at least four ways of decoding the signal in rectangular coordinates and two in polar (circular) coordinates. Should anyone think this strange we would remind them that at least one ancient language is written in spiral format.

Even if the right format *is* chosen, there is no guarantee that the message can be read. Perhaps the best illustration of the problem was given when one prominent journal printed the intended pictogram upside down! If we Earthlings get *our* homework wrong, can we expect others to get it right? [8,9].

Some hard facts must be faced:

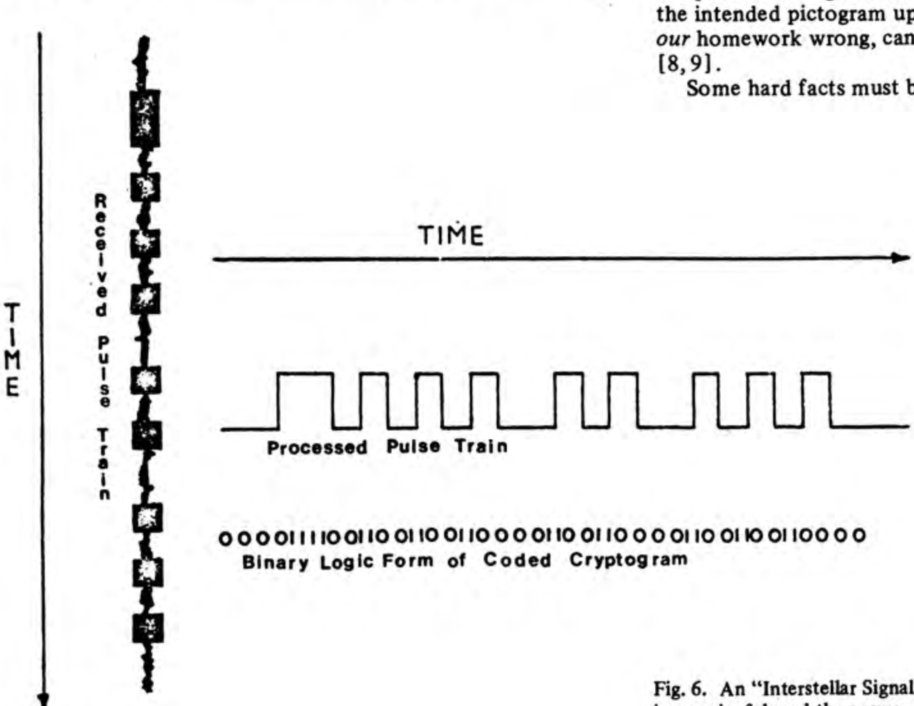


Fig. 6. An "Interstellar Signal'. Can you 'decode' it? The "message" is meaningful, and the answer is given at the end of the paper.

- We really do not know the best way to communicate over interstellar distances or what medium to use.
- CETI or SETI (Search for Extra Terrestrial Intelligence) costs a great deal of money.
- Of the 100 or so large radio telescopes at present in use, only one (possibly two) is being used for such work.
- The other 98 could quite simply be used for CETI work as piggyback experiments by using an additional amplifier with short time constant filters on the output prior to recording. This is not done simply because it involves an enormous amount of effort in examining literally thousands of feet of paper or tape, and the professionals do not have the time and effort to do it. However, a professional society could possibly organise an amateur effort.

A CETI Rethink!

Clearly, massive effort is required in terms of scanning the whole of the Cosmos in a spectral sweep ranging from X-rays down to (say) radio waves at 600 MHz (50 cm). Some [10] have suggested that the event is so rare and the probability so unlikely that we should not even try! Although sympathetic we are not that pessimistic! If we do not start to search, we shall not find!

The "searchers" *do not* have to be skilled technicians or scientists but they *do* need to be trained to be alert to "the unusual".

Perhaps the best example of being 'alert to the unusual' was the finding of the first pulsar by Jocelyn Burnell. This was a serendipitous discovery; but a *trained* team of technicians with *far* lower grading than Burnell could also have made such a discovery.

This problem of searching on a large scale for a rare phenomenon is not entirely unknown. A close matching parallel in terms of effort and actual work format is that of searching for proof of weak nuclear reactions in the so-called "charmed particles"*. These are extremely rare events, and the work programme demanded the continued particle bombardment of a suitable liquid "target" housed in an enormous bubble chamber. The search effort required the intense detailed scanning of one million photographs, the viewers looking for a particular pattern format. In fact 735,000 photographs were scanned before the first correct pattern was identified!

The original dogged effort in tracing charmed particles was done by relatively unskilled people who had been carefully trained to look for the "signature" of charm.

Nowadays the particles produced by a "tuned" accelerator are recorded by computer and the "eye breaking" search for signatures is over.

A search for alien signals could follow a similar pattern. All radio telescopes engaged in sky surveys would have duplicate but entirely separate amplifiers and recorders (preferably tape) with a bandwidth of (say) 500 Hz. At regular intervals these tapes would be replayed at various speeds, preferably higher than the recording rate. The underlying reason for this is that an alien signal may have a bandwidth of only 10 Hertz and playing back at higher speed would produce an audible note, whilst the majority of the man-made signal interference would be ultra sonic and could be eliminated. If the tape were overspeeded 10 times on playback, then a 24 hour tape could be cleared in 2½ hours and returned for further recording.

Although we have, over the last decade, tried to map out what may be a logical system, with obvious universal understanding and minimum difficulty in decoding, we still do not know what we are looking for in terms of how an alien message may be conveyed or coded.

We therefore think that CETI work should have a more international foundation, essentially along the lines of IGY (International Geophysical Year), and select (say) 100 Sunlike stars to be examined over a wide range of wavelengths (at least optical to radio) for signals. A second batch of stars should then be searched – and so on.

After this we can have the luxury funding for Cyclops complete with its auto correlation imaging system and computer.

But, as in the case of charmed particles, there will need to be a phase of sheer hard drudgery, before we have 'alien voices to order', and we may need to search 735,000 stars before we find anything!

* *Heavy quarks – particles which have mass but no charge and yet behave differently to a neutron.*

Acknowledgements

The authors wish to thank Dr. J. Best for helpful discussions and Mrs. A. Lawton for her patience in preparing the manuscript.

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Answer to CETI Code (Fig. 6). *The code is the well-known Morse Code. The Cryptogram spells out the letters: BIS.*

OBSERVATIONS OF 1977-66A, COSMOS 929

By The Kettering Group

Introduction

Cosmos 929 was launched from Tyuratam at 0900 GMT on 17 July 1977 into an 89.4 min, 51.6° inclination orbit. During its flight the spacecraft made an intricate series of orbital manoeuvres. The orbital period as a function of time is shown in Fig. 1. The information for this figure was taken from NASA, Goddard Space Flight Center, "two-line" orbital elements.

The flight can be divided into four phases on the basis of orbital period.

(1) Cosmos 929 was maintained in a low orbit by a series of four minor burns. Following natural decay to 88.6 min, a major burn on 18 August raised the period to 90.8 min.

(2) Four minor burns during the two weeks following 18 August raised the period to 90.95 min and the orbital heights to 314-329 km. Minor burns were made during the three weeks prior to 19 December.

(3) A major manoeuvre during rev 2472 on 19 December raised the orbital period to 93.42 min and the orbital heights to 440-448 km.

(4) A retro-burn during rev 3146 on 1 February 1978 lowered the orbital period to 92.28 min and the perigee to 336 km whilst the apogee remained at 437 km. On 2 February the spacecraft was deorbited and decayed over the Pacific Ocean.

Following the large manoeuvre on 18 August the *New York Times* hinted that some part of Cosmos 929 was detached before the change of orbit [1].

Shortwave Telemetry

Cosmos 929 transmitted frequency-shift-keying (f.s.k.), pulse-duration modulation (PDM) signals on 19.945 MHz. Signals received at Rothwell on the first four revolutions and in the U.S.A. later in the day indicated that the transmitter was operating continually. An example of one f.s.k.-PDM telemetry frame is shown in Fig. 2.

During the frame duration of approximately 16 sec, sixteen equal word-length intervals are available. Fifteen of these are used to transmit data whilst the other, word O, contains a synchronisation pulse-train. The f.s.k. transmitter is switched between two radio frequencies, f_H and f_L, 1 kHz apart. At the beginning of a data-word interval, f_H is turned on. At some time before the end of the interval, f_H is turned

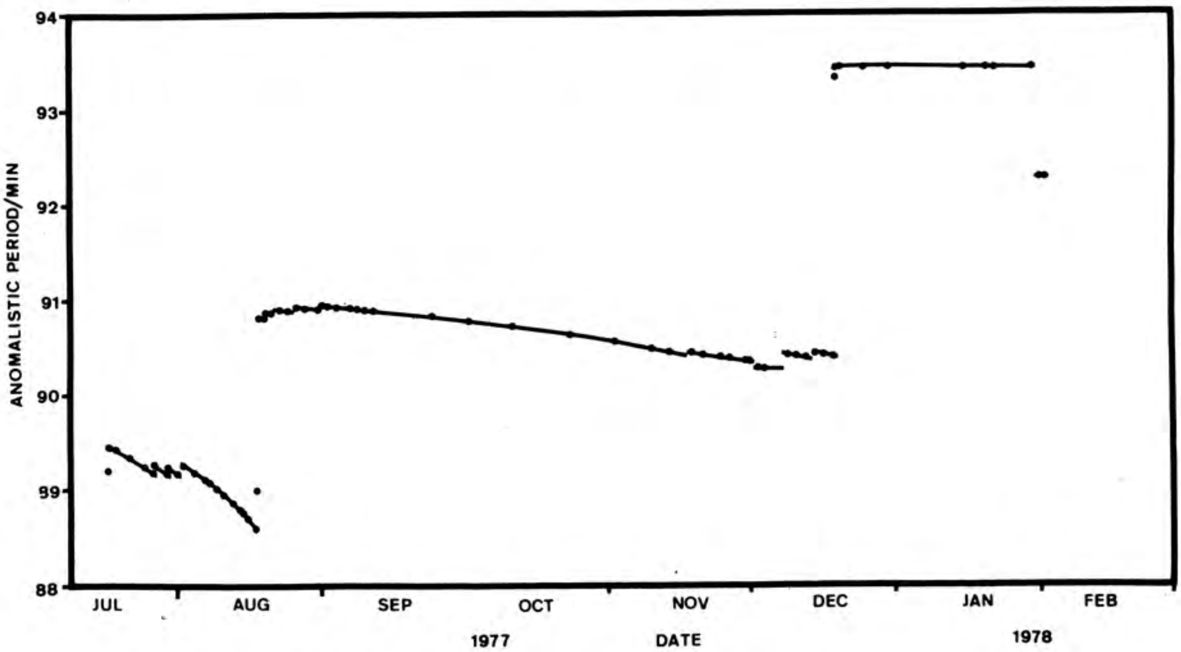


Fig. 1. Orbital history of Cosmos 929.

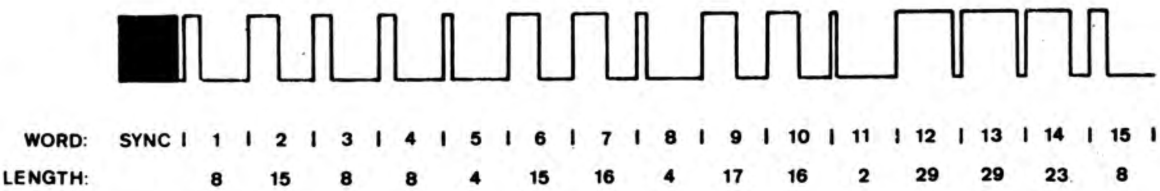


Fig. 2. Mode-B shortwave telemetry frame. Cosmos 929. 0955 GMT 21 July 1977.

off and f_L is simultaneously turned on, and remains on until the end of the interval. The ratio of the duration of f_H to $f_H + f_L$ is a measure of the data value being transmitted. It has been shown, [2], that there are 32 possible times within a word when the f_H to f_L transition can occur. The analogue data being sampled has been quantised in one of 32 possible levels. The permissible f_H to f_L transition times are defined in the synchronisation pulse-train which normally contains 29 pulses. In the remainder of this paper word-values will usually be expressed in the form of integers ranging from 1 to 32, where 16 corresponds to f_H being on for 50% of the word-interval.

Cosmos 929 f.s.k.-PDM Telemetry

Two separate telemetry modes were transmitted on a time-sharing basis. During phase 1, mode A was characterised by a 30-pulse synchronisation train and word 14 taking the value 15. In the last three phases of the flight the mode A synchronisation contained only 29 pulses. Throughout the flight mode B was characterised by a 29-pulse synchronisation train and word 14 taking the value 23.

One telemetry mode was transmitted for 30 min and then replaced by the other for 30 min, after which time the cycle was repeated. Mode changes occurred at 28 min 55 sec and 58 min 55 sec past the hour at first, indicating that the on-board timer controlling the change-over was started at the estimated lift-off time of 0900 GMT. During the flight the times of change-over became progressively earlier at a rate of 0.116 sec day^{-1} and were occurring at 28 min 30 sec and 58 min 30 sec by 8 January, the last occasion on which they were determined.

The change of mode could occur at any word within the frame being transmitted. Thus the duration of a mode was not an integral multiple of the frame-length. Moreover, the commutators sampling mode A and mode B data were not synchronised since modes generally ended and commenced on different words within each frame. The word transmitted immediately following a mode-change was simply whatever word the second commutator happened to be sampling at the time of the change. Although the two commutators were not synchronised, their cycling-rates were very nearly identical as evidenced by the fact that mode A and mode B frame-durations were equal to within ± 20 millisec.

Different transmitter frequencies were employed for modes A and B. For mode A, f_H = 19.954 MHz and f_L = 19.953 MHz. For mode B, f_H = 19.955 MHz and f_L = 19.954 MHz. The frequency change associated with change of mode permitted stations without access to pen-recorders to observe the change without difficulty.

Table 1, giving word-lengths on 22 July, shows that, in general, values of the transmitted data words in modes A and B were quite similar.

It should be emphasised that word 14 assumed significantly different values depending on the mode. These values were constant throughout the flight and could be used to easily determine which mode was being received. Many of the data-words were not constant and showed significant long term variations. Fig. 3 shows the value of word 3 in both modes over a two-month interval. Although a considerable change in value occurs during this period, the values in both modes at any given time are very similar. With the exception of word 14, all data-words showed good inter-mode agreement throughout the flight.

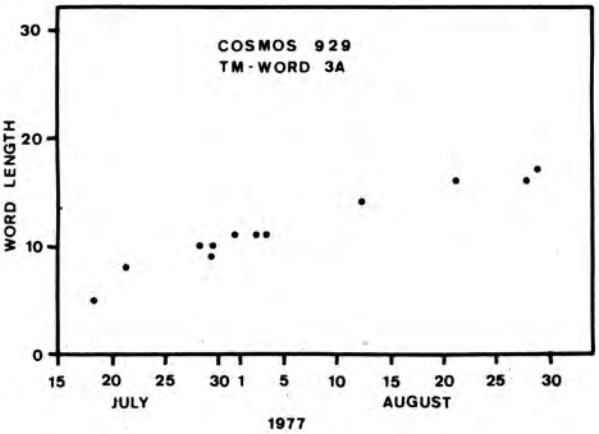
Following the manoeuvre of 19 December, a dramatic change occurred in the data-word values. Words 2-11, in both modes, assumed a constant value of 16 whilst words 12-15 continued to show the same values as they had earlier in the flight.

Conclusions from Shortwave Telemetry Observations

1. Two separate commutators controlled by different time-bases were employed.
2. The commutator outputs were transmitted on a time-sharing basis with approximately 30 min devoted to each mode in turn.
3. The selection of mode was controlled by an on-board timer which apparently was started at lift-off.

Table 1. Data-Word Values on 22 July 1977.

Word No.	Mode A	Mode B
0	30 pulses	29 pulses
1	7	8
2	14	14
3	8	8
4	7	8
5	4	4
6	14	14
7	16	16
8	2	4
9	16	17
10	15	17
11	2	2
12	29	29
13	29	29
14	15	23
15	7	8



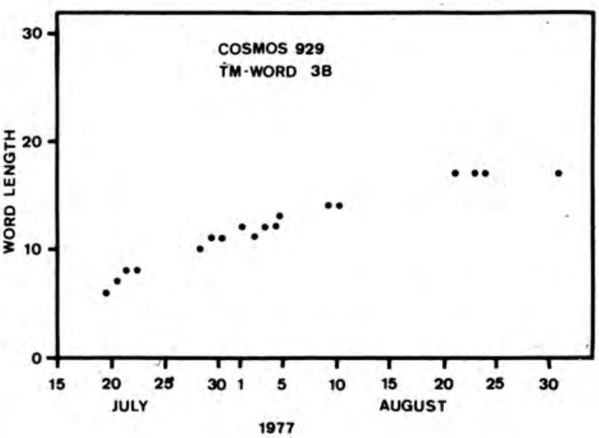


Fig. 3. Values of data-word 3 in each mode during July and August 1977.

Table 2. Kettering Group Stations and their Participation in Cosmos 929 Observations

Station	Operator	Location	Reception Frequencies	Pen-records	Visual
Bahrain	Peter Wakelin	26.0°N 50.4°E	19.954 MHz	-	Yes
Bude England	Geoffrey Perry	50.8°N 4.5°W	19.954 MHz	-	Yes
Fort Worth Texas, USA	Mark Severance	32.8°N 97.6°W	19.954 MHz	-	Yes
Gainesville Florida, USA	Richard Flagg	29.6°N 82.4°W	19.954 MHz	Yes	Yes
Kettering England	Geoffrey Perry Kettering Boys School	52.4°N 0.7°W	19.954 MHz	Yes	Yes
Malmö Sweden	Jan-Ola Dahlberg	55.6°N 13.0°E	19.954 MHz	-	-
Rothwell England	David Muggleton	52.4°N 0.8°W	19.954 MHz	-	Yes
Sollentuna Sweden	Sven Grahn	59.2°N 18.1°E	19.954 MHz 166.0 MHz	Yes	-
Stevenage England	David Hawkins	51.9°N 0.2°W	19.954 MHz	-	Yes

4. The data-bases sampled by each commutator were similar. However, there is no direct evidence to indicate the size or complexity of the sub-assemblies being monitored. It is known that the Soviet Union uses single 16-step commutators on first generation recoverable Cosmos satellites, and on Soyuz and Salyut spacecraft for the transmission of shortwave PDM telemetry. From this it could be argued that the sub-assemblies were similarly large and complex. On the other hand, since the ground stations are equipped to handle this format it would have been expedient to install two similar commutators even if the sub-assemblies to be monitored were relatively small.

5. The two commutators cycled at slightly differing rates indicating the use of separate timing systems.

6. Three different frequencies were used to transmit the two f.s.k. modes. The three frequencies could have been generated by two independent transmitters having one frequency in common. The possibility exists that a single transmitter capable of generating all three frequencies was coupled to the two commutators. During phase 3 an RF instability was noted during the transmission of one of the modes and, although not conclusive, this could indicate that two separate transmitters were used.

7. In general, the received signal strength was independent of the mode being transmitted. From this it can be concluded that if two transmitters were used they had similar output powers. On a few occasions a change in received signal strength was observed at mode change. This could be explained if separate transmitting antennae were used. The same signal strength would generally be received from either antenna if they had similar radiation patterns. However, there could be certain restricted viewing angles which would result in different signal strengths due to partial blockage of radiation from one antenna by the spacecraft.

VHF Telemetry

Wideband telemetry on 166.0 MHz was received on the second day of the flight. Signals were similar to those transmitted by Soyuz and other Soviet spacecraft and appear to be double-sideband suppressed carrier AM transmissions with a bandwidth of approximately 300 kHz. The transmissions, which were commanded-on from Soviet ground stations, changed pitch a few minutes after command-on, possibly indicating that the telemetry system changed from real-time data transmission to read-out of an on-board data recorder.

166 MHz telemetry was only received during the first phase of the flight when Cosmos 929's orbit was being maintained at a relatively low altitude between 214-278 km. The last reception of such signals was recorded on 16 August. Attempts to receive such signals on 20 August and later dates were unsuccessful. By then the manoeuvre to the higher orbit of phase 2 had occurred and it is probable that a portion of the spacecraft had either been deactivated or separated and possibly returned.

Visual Observations

Several visual observations of Cosmos 929 were made throughout the flight. It appeared generally as a steady object of stellar magnitude ranging from - 0.2 to + 3 depending on the phase of the flight and the position of the spacecraft in relation to the Sun and the observer. On 2 September it was observed to flash momentarily up to a brilliance of mag - 0.5. Such flashes have been observed from the solar panels of Salyut spacecraft when the Sun-spacecraft-observer angle satisfies the law of reflection and on this occasion Cosmos 929 was in the appropriate part of the sky.

Conclusions from Visual Observations

Cosmos 929 was a very large spacecraft,probably equipped with solar panels which would account for the sharp variation in brightness observed on 2 September.

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IN PREPARATION. "Forerunners of the Space Shuttle" is the title of a series of articles to appear in the near-future. The first describes the Von Opel Flights of 1928-1929.

T 32

SATELLITE DIGEST - 119

Continued from August issue p. 214]

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information sources include the Royal Aircraft Establishment at Farnborough, NASA, Novosti and both the popular and specialist press. For a more detailed summary, see Satellite Digest – 111, January 1978.

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
1978-38A	1978 Apr 8.03 indefinite	Cylinder 700 fuelled	1.7 long? 1.4 dia?	149 geosynchronous orbit	189	29.9	87.72	ETR Atlas Agena D DoD/USAF (1)
BSE 1 1978-39A	1978 Apr 7.92 indefinite	box 678	approx 2 m each side	164 35115 35784	35653 35662 35786	27.23 0.10 0.08	627.64 1415.75 1436.0	ETR Delta Japan/NASA (2)
Cosmos 1003 1978-40A	1978 Apr 20.65 13.6 days (R) 1978 May 4.3	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	178 162	328 279	62.81 62.81	89.54 88.89	Plesetsk A-2 USSR/USSR (3)
HCMM 1978-41A	1978 Apr 26.43 60 years	Hexagonal prism 134	0.64 long 0.7 wide	559	651	97.60	96.85	WTR Scout NASA/NASA (4)
AMS 3 1978-42A	1978 May 1.13 80 years	Irregular cylinder 513	6.40 long 1.68 dia	820	835	98.71	101.47	WTR Thor Burner 2 DoD/USAF (5)
Cosmos 1004 1978-43A	1978 May 5.65 12.6 days (R) 1978 May 18.3	Sphere + cylinder-cone 5500?	5 long? 2.2 dia?	205	290	62.81	89.43	Plesetsk A-2 USSR/USSR
OTS 2 1978-44A	1978 May 11.96 indefinite	Box + 2 panels 865 fuelled 444 empty	2.13 long 1.68 wide 2.39 high	35072	35779	0.1	1417	ETR Delta ESA/NASA (6)
Cosmos 1005 1978-45A	1978 May 12.17 60 years	Cylinder + 2 vanes? 2500?	5 long? 1.5 dia?	625	652	81.24	97.54	Plesetsk A-1 USSR/USSR
Cosmos 1006 1978-46A	1978 May 12.46 15 months	Cylinder?	4 long? 2 dia?	382	407	65.85	92.45	Plesetsk C-1 USSR/USSR
NDS 2 1978-47A	1978 May 13.44 indefinite	Cylinder + 4 vanes 453		142 19958	20077 20094	62.66 63.13	351.157 711.65	WTR Atlas F DoD/USAF (7)
Cosmos 1007 1978-48A	1978 May 16.45 12.8 days (R) 1978 May 29.2	Sphere + cylinder-cone? 5500?	5 long? 2.2 dia?	168	350	72.83	89.75	Plesetsk A-2 USSR/USSR
Cosmos 1008 1978-49A	1978 May 17.61 10 years	Cylinder + paddles? 900?	2 long? 1 dia?	497	548	74.04	95.12	Plesetsk C-1 USSR/USSR
Cosmos 1009 1978-50A	1978 May 19.01 0.18 day 1978 May 19.19	Cylinder?	4 long? 2 dia?	145 965 537	950 1384 1006	65.2 65.84 65.73	95.6 108.86 89.19	Tyuratam-Baikonur F-1-m USSR/USSR (8)
Pioneer Venus 1 1978-51A	1978 May 20.55 indefinite	Cylinder 582 (fuelled) 368 (in Venus orbit)	1.2 long 2.5 dia	heliocentric orbit				ETR Atlas Centaur NASA/NASA (9)
Cosmos 1010 1978-52A	1978 May 23.31 12.9 days (R) 1978 Jun 5.2	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	215	229	81.38	89.00	Plesetsk A-2 USSR/USSR (10)
Cosmos 1011 1978-53A	1978 May 23.70 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	960	1014	82.91	104.90	Plesetsk C-1 USSR/USSR (11)

Supplementary notes:

(1) US early warning satellite designed to monitor missile launchings.

(2) Experimental communications satellite, its full name is Medium Scale Broadcasting Satellite for Experimental purposes.

The satellite will test methods of transmitting colour TV to the Japanese islands and Okinawa. Its operating position is over Borneo at longitude 110 degrees East.
(3) A manoeuvring engine separated during 1978 May 3, it is designated 1978-40D. Orbital data are at 1978 May 20.9 and 1978 May 23.9.
(4) Heat Capacity Mapping Mission, designed to produce thermal maps of the atmosphere. The orbit is to be circularised at 620 km altitude.
(5) US Air Force Advanced Meteorological Satellite.
(6) Replacement satellite for OTS-A which was lost when the first stage of the launch vehicle exploded 55 seconds after launch on 1977 Sep 13. Responsibility for building the satellite was given by ESA to British Aerospace. The craft is experimental and is designed to test methods of communication. It is stationed at longitude 10 degrees East.
(7) US navigation satellite. The system uses measurements of the time taken to transmit a signal to and from the satellite rather than the more commonly used Doppler system. A positional accuracy of 10 m on the Earth's surface can be obtained.
(8) Satellite interception test. The target was Cosmos 967 (1977-116A – see Satellite Digest 115, May 1978). The interception was made at the start of the third orbit, near 51 deg North, 14 deg East. Immediately afterwards, the interceptor was placed on a descending trajectory and re-entered the atmosphere over the Western Pacific. The initial orbital data shown are of the carrier rocket, the others are immediately before and after the interception at 1978 May 19.16.
(9) First of a pair of NASA craft to fly to Venus during 1978. Pioneer Venus 2 is scheduled for launch during early August; this latter craft will carry 4 atmosphere probes. Pioneer Venus 1 is intended to enter orbit around Venus at 1978 Dec 4, after braking by a small solid rocket motor. It will make both direct and indirect measurements of the electromagnetic environment and the atmosphere of the planet.
(10) Cosmos 1010 carried an Earth Resources observation package. A package of scientific instruments was separated on 1978 Jun 4, designated 1978-52C.
(11) Cosmos 1011 may be a navigation satellite.

Amendments and decays:
1974-40A, Explorer 52 decayed 1978 Apr 30, lifetime 1427 days.
1976-83A, Cosmos 849 decayed 1978 Apr 24, lifetime 614 days.
1977-97A, Salyut 6 was manoeuvred to a higher orbit to prevent premature decay on 1978 May 16. The initial parameters of the new orbit were: 321 x 362 km, 51.63 deg, 91.30 min.

CORRESPONDENCE

United States Missile Ranges
Sir, I read with much interest the article "United States Missile Ranges: Origin and History," by David L. Skinner, in the March issue of *Spaceflight*. But in a list of 44 references I was aghast at not seeing: Sharpe, Mitchell R. and Lowther, John M., "Progress in Rocket, Missile, and Space Carrier Vehicle Testing, Launching, and Tracking Technology, Part I: Survey of Facilities in the United States," in F. I. Ordway, ed., *Advances in Space Science and Technology*, Vol. 6, NY: Academic Press, 1964. I also was disappointed not to find two other excellent publications listed. These are Albert B. Christman, *Sailors, Scientists, and Rockets, Origins of the Navy Rocket Program and of The Naval Ordnance Test Station, Inyorken,* Washington: Naval History Division, 1971; and Gordon L. Harris, *Kennedy Space Center Story,* Kennedy Space Center, December, 1971.

Several years back, I remember seeing a draft of a history of Bob Krieger's Wallops Island range, but I do not know whether it was ever published.

MITCHELL R. SHARPE,
Huntsville, Alabama, USA.

Utility of Shuttle Tank
Sir, The Space Shuttle External Tank surely must be one of the greatest blessings-in-disguise in astronautical history. It seems that uses for it keep coming up all the time. First, Gerard O'Neill proposed that the tanks be pelletized to provide fuel for his mass drivers [1]. Then, NASA Marshall studied the possibility of converting the ET in orbit for use as a rudimentary space station [2]. And recently, Shettler has added ET LH_2 tanks transformed into space habitats to the space industrialization plan [3].

I would like to propose two more possible uses for ET hardware. The first is a reusable LO_2/LH_2 Orbital Transfer Vehicle for transporting people and equipment to and from Geosynchronous orbit (Fig. 1). It takes the form of an ET LO_2 tank, with a new internal bulkhead to separate the propellants and two Advanced Space Engines [4] for propulsion. With an empty mass of 10 tons and a propellant mass of 218 tons, such an OTV could carry 30 tons of payload to GEO and back, or 120 tons one way.

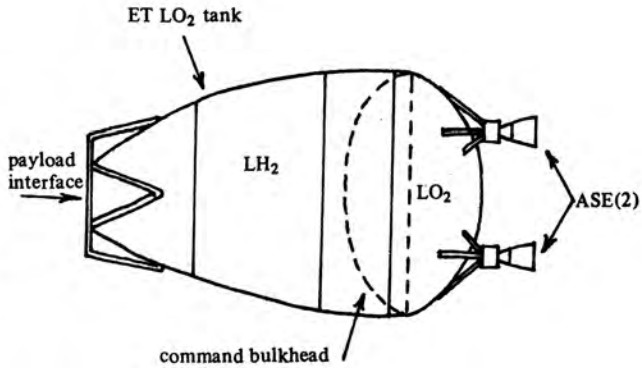

Fig. 1. ET-derived Orbital Transfer Vehicle.

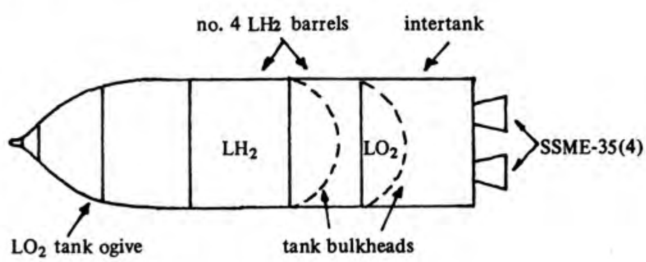

Fig. 2. ET-derived Space Shuttle Booster.

The second application involves the development of LO_2/LH_2 boosters for the Shuttle to replace the SRB's [5]. Considerable savings could be effected if these were to be built

from existing ET components. Such a booster (Fig. 2) would consist of the ET ogive section, two LH_2 no. 4 tank barrels, two domes (with the existing LO_2 and LH_2 feed systems) and the intertank (with a thrust structure mounting 4 SSME-35 engines). Each booster would be about 29 m long, have an empty mass of some 45 tons, and have a loaded mass of 370 tons.

VERN SEGUIN,
Edmonton, Alberta, Canada.

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Space: The Battle for Social Support

Sir, As we consider the long-term future of space flight we should remember the lesson of the recent past: that good engineering is not enough; social factors such as public acceptance and the efficient management of space activities are the most significant factors controlling the pace of progress in space.

The Apollo project succeeded in carrying men to the Moon and back, but failed to achieve its potential of establishing a lunar scientific base because it became fatally unpopular; it was an engineering success but a social failure.

Present-day technology could be developed to build a lunar base, carry explorers to Mars or begin the long task of developing an independant space colony, but these things will not happen until space flight is shown to be as socially useful as it is technologically successful.

The next twenty years – the Shuttle era – will provide an opportunity to show that space flight is a useful, socially desirable activity. At the end of this twenty year demonstration that we can "live off the land," the next phase of the humanization of space can begin – industrialization and colonization.

When the time comes for the would-be founders of the first space colony to choose solutions to technological problems they will choose the most familiar and conservative because such solutions will be most likely to allay the fears of the dubious and the sceptical. The same motives will lead the colonizers to choose familiar and well-tried solutions to the problems of social organization.

The social technology of the colony will be made as conventional and familiar as possible, as will the physical technology, and for the same reason – familiarity breeds confidence, and so promotes social acceptance and success.

If the battle for social support is won, and the necessary resources are committed to the colony, it is reasonable to suppose that the social system, economics and governmental methods will be as similar to those of the founding society as possible, both to satisfy the backers that no unnecessary risks are being taken, and to give the colonists as familiar and reassuring an environment as possible. It is no accident that the most detailed and authoritative descriptions of life in the space colony sound so much like California-in-the-sky.

Many writers hope that the Society of Space will be able to develop along new lines, providing new opportunities for experiments in living, allowing groups of people to set up their own model societies and test new ideas. H. E. Ross expressed this hope for a new start for humanity with the words "For the first time since Adam the slate is clean." But just how clean can we expect the slate to be?

If the governmental systems of Earth are used within the colony the lives of the colonists will be divided into working time and non-working time; the major policy decisions in the "working" sector being made by the colonies backers, while the "non-working" sector would be controlled democratically by the colonists themselves.

The economy of the colony might be designed to simulate that of the founding society: this would obviously be an artificial system, serving no purpose beyond making the colonists feel "at home." If the prices of the products of the colony farms were set at their real levels, the colonists would have to be paid in units of a million dollars (think of the cost of food in a world where "land" costs 30 billion dollars/acre). If an Earth-type economy were to be adopted the social engineers would have to decide where to place the dividing-line between their artificial system and the realities of the space environment: would the colonists be expected to pay for food? for air? for gravity? It might be more reasonable to follow the military system, and have the colonists draw supplies from stores as they were required. In a colony operating such a "stores" economy, money would be redundant, even its familiarity-value being eroded by the fact that the Earth will have entered the cashless society by the time the first colony is built (the colonists will hardly be reluctant to leave their credit cards on Earth).

Should the social engineers choose the "stores" economy, they will have the opportunity to avoid many of the social ills of terrestrial society, since they might consider an equal division of the produce of the colony, an equal share of any industrial profit and a generally egalitarian society to be a safer option than risking the possibility that "New Earth" might be a more complete and accurate replica than they intended to produce.

The "slate" presented to the initial population of the colony will not be clean: it will be half-covered with predecided policies and objectives, and whatever the would-be colonist finds written on it, he or she will have to chalk an assenting signature on the bottom before being allowed to join the colony. Despite this, the social environment of the colony will be almost an unusual as the physical environment of the lunar surface or Earth orbit, and the social technologies needed to deal with such a social environment will inevitably call for new ideas and present new opportunities. The slate may never be clean, but the space environment presents a very big and a very unusual slate.

DAVID C. SPEED,
Broadlands, Colchester.

Postal Black Hole

Sir, Many thanks for the copy of *Spaceflight* (June 1978) mailed to me, after my original issue disappeared down a postal black hole.

Your prompt action in this matter has been appreciated, and I must comment that the efficient service maintained by the Society is very welcome at such a time when most other company-customer relations lurch from bad to worse. Quite clearly, you are top of the league!

HOWARD HAIGH
Eccles, Lancs.

SPACEFLIGHT

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MEDIA PUBLICITY

We work hard to secure publicity on radio, TV, and in the News Media, but the local press is often an untapped field which members could use to open discussions on space matters, e.g. by writing letters or getting friends to do so. Often this will bring down local reporters for an interview. There may be events, local connections or activities which would be useful for additional cover. Staff or House Magazines are a similar source of publicity, with the advantage that they are often looking for articles, too. References to the Society (particularly its address) can be most valuable. The same applies to authors preparing books on astronomy and spaceflight, who might like to work in a reference to the Society, or to their connection with its work.

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Even more valuable is the work which individual members can do in persuading friends, colleagues or acquaintances to join, once they have expressed a positive interest in the subject. This is probably the finest "go-getter" of all. It provides an opportunity to discuss the Society's work so that those who subsequently apply are well informed on what we do, how we operate, and what we are trying to achieve.

1979 SUBSCRIPTIONS

No change has taken place in the basic Subscription Rates for 1979, which are detailed below. Renewal forms appear in this issue of 'Spaceflight'.

	Sterling	*US Dollars*
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12 Bessborough Gardens, London, SW1V 2JJ

JBIS "RED COVER" ISSUES

Four issues of *JBIS* devoted to Interstellar Studies are planned for 1979. The cost will remain the same as last year, i.e. £4.00 (\$8.00) post free.

Members not normally receiving *JBIS* but who would like these Special Issues may either remit separately or add this item to their normal subscription renewal notice and send it in due course to the Executive Secretary at 12 Bessborough Gardens, London, SW1V 2JJ.

Early notice of the wish to receive copies is advisable since, owing to the high cost, extensive stocks of back issues of *JBIS* cannot be carried.

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: Tel: 01-821 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor 12, Bessborough Gardens, London, SW1V 2JJ.

29th I.A.F. Congress
The 29th Congress of the International Astronautical Federation will be held in Dubrovnik, Yugoslavia, from **1-8 October 1978.**

Further details appear on p. 360 of the Sep-Oct issue of *Spaceflight*

Film Show
To be held in the Botany Lecture Theatre, University College London, Gower Street, London, WC1 on **11 October 1978,** 6.30-8.30 p.m.

The programme will be as follows:

(a) Reading the Moon's Secrets
(b) Mercury, Exploration of a Planet
(c) HEAO, the New Universe
(d) Images of Life

Admission tickets are not required. Members may introduce guests

Guest Lecture
Title **AN AMERICAN VIEW OF SETI** by Dr. John Billingham, Chief, SETI Program Team, National Aeronautics and Space Administration.

To be held in the Botany Lecture Theatre, University College London, Gower Street, London, WC1 on **17 October 1978,** 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests

Visit
A tour of the Astronomy and Space Gallaries of the Science Museum, Exhibition Road, London, S.W.7, accompanied by Dr. John Becklake, will take place on **2 November 1978,** commencing at 6.30 p.m.

Admission (members only) will be by ticket. These are available from the Executive Secretary on request enclosing a **reply-paid envelope.**

Film Show
To be held in the Botany Lecture Theatre, University College London, Gower Street, London, WC1 on **15 November 1978,** 6.30-8.30 p.m.

The programme will be as follows:

(a) Remote Possibilities
(b) The Weather Watchers
(c) If One Today, Two Tomorrow
(d) Mercury, Exploration of a Planet (Repeat)

Admission tickets are not required. Members may inroduce guests.

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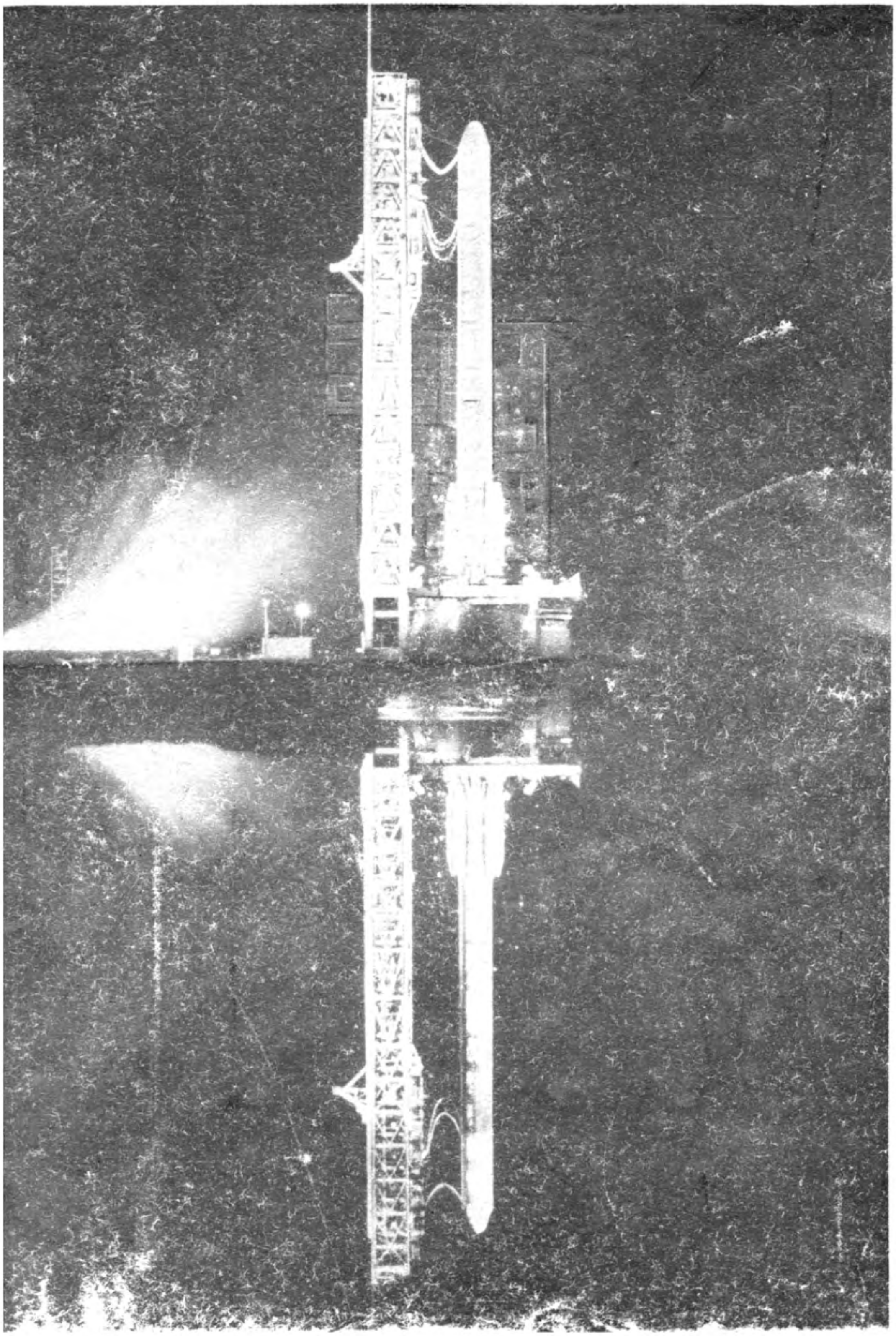

SPACEFLIGHT

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Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

COVER

DOUBLE IMAGE AT THE CAPE. Delta rocket poised on Launch Complex 17 ready to launch the European Space Agency's scientific satellite GEOS 2 on 14 July 1978. The satellite was subsequently placed into a geostationary orbit at 6 deg E. longitude to study the Earth's magnetosphere. GEOS 2 data will be correlated with data acquired by the three ISEE satellites, consisting of ISEE 1 and ISEE 2 (an ESA satellite) launched in October 1977, and ISEE 3 launched in August 1978. In this way it is hoped to collect a large amount of data on the magnetosphere and to enable an overall understanding of the effect of processes in interplanetary space on the near-Earth environment.

National Aeronautics and Space Administration

MILESTONES

July

6 Doubts are expressed within NASA that Space Shuttle can meet the revised launch date of late June 1979. Development problems with the main engines are likely to cause further slippage, placing doubt on ability to fly Skylab re-boost mission before station decays from orbit. (*Launch target is now "last quarter of 1979." Ed.).*

6-10 High level US delegation of science and technology led by Dr. Frank Press, presidential science advisor, visits People's Republic of China to discuss cooperation in space research. Delegation includes NASA Administrator Dr. Robert A. Frosch.

7 Fourth test of three Shuttle Main Engines mounted in an Orbiter aft fuselage – plus External Tank and associated systems – is successful at NASA's National Space Technology Laboratories, Bay, St. Louis. During the test,engines were throttled from 90 per cent down to 70 per cent, then back to 90 per cent. (Engines have now been removed from test stand for modification and updating to current specification in readiness for further firings late this year.
During this next critical series of tests, engines will be run at rated power levels (1.67 million newtons or 357,000 lbf at sea level for more than the 500 seconds needed to lift the Shuttle into orbit. Ed.).

7 Soviets launch Progress 2 automatic space freighter from Tyuratam at 14 hrs 26 min (Moscow time). Orbit parameters are 193 x 262 km x 51.6 deg; period 88.7 mins.

7 ESA confirms that Agency's first communications satellite OTS 2 is functioning correctly at the end of the eight weeks' period covered by the insurance contract.

9 Progress 2 docks with Salyut 6/Soyuz 29 complex at 15 hrs 59 mins (Moscow time). The space freighter carries scientific equipment, photographic materials, replacement instruments, food, water and life support materials in a cargo compartment which can accommodate 1,300 kg. (Foodstuffs 235 kg; water 187 litres, sufficient for two men for 50 days). A second compartment contains fuel tanks and gas cylinders for the refuelling operation.

[Continued overleaf

BIS DEVELOPMENT PROGRAMME

GOOD NEWS FOR MEMBERS

"SPACEFLIGHT" TO BE 48 PAGES NEXT YEAR

As part of our effort to increase the flow of information on Astronautics – and make more effective use of pictures in our larger format – ***Spaceflight*** **is being increased to 48 pages from the January issue. In conjunction with our printers, we shall also hope to speed up production of our magazine by at least a week. Another improvement will be to include the Volume and Issue numbers and date on each page for ease of reference, particularly important in the case of reprints of individual articles.**

10 Skylab again develops power problem which causes it to lose orientation. JSC spokesman says station may have to be repositioned to recharge its batteries. (*A similar problem was corrected a month earlier. Ed.).*

11 Thirty-five new astronaut candidates begin two-year training and evaluation programme at Johnson Space Center, Houston, Texas.

11 Large solar flare breaks out from region of major sunspot activity.

11 Skylab power is temporarily shut off, causing station to roll out of its stable position.

12 NASA selects TRW Defense and Space Systems Group for negotiations leading to award of a $9.7 million contract for the Materials Processing in Space Shuttle-Spacelab programme. TRW will serve as prime contractor for the initial phase of the programme to begin September 1978 and last until end of 1981.

14 NASA launches ESA 573 kg satellite GEOS 2 from Cape Canaveral by Delta 2914 at 10.43 hrs GMT to study magnetosphere from geo-stationary orbit.

15 Apogee boost motor puts GEOS 2 into geo-stationary orbit at 23.59 hrs GMT by telecommand from European Space Operations Center (ESOC), Darmstadt, West Germany. (*GEOS 2 is ESA's eleventh scientific satellite. Ed.).*

17 Cosmonauts aboard Salyut 6 use new furnace 'Kristall' delivered by Progress 2 to grow monocrystal of gallium arsenide from a high temperature solution. Crew also work with the 'Splav' furnace to obtain new semi-conductor materials and alloys of aluminium, tin and molybdenum.

18 *Novosti* reveals that cosmonauts aboard Salyut 6 have conducted first experiment in fusing glass for optical purposes in space conditions. Object is to find a method of shaping lenses and mirrors under weightlessness which makes further surface treatment unnecessary. Several ampoules of fused glass will be returned to Earth for study.

18 Soviets launch Raduga 4 by Proton rocket from Tyuratam into geo-stationary orbit for round-the-clock telephone and telegraph communications and simultaneous transmission of colour and black and white programmes of Central Television to the Orbita network of ground stations.

19 Temporary fault aboard Skylab turns on attitude thruster, causing station to roll and waste 810 kg of fuel. (NASA estimates that between 2,340 and 4,500 kg of fuel remain).

20 Spacecraft controllers at NASA's Ames Research Center, Mountain View, California, complete final course targeting for Pioneer 11's encounter with Saturn on 1 September 1979. Craft will fly to within 30,000 km of edge of Saturn's outer ring, then will swing under the plane of the rings to 25,000 km from planet's surface. Pioneer 11 will take first close-up colour pictures of Saturn and its rings and make other first-time measurements of its magnetic field, atmosphere and other features. (see 'Probing Saturn's Rings,' *Spaceflight*, April 1978, pp. 150-152).

21 Salyut 6 cosmonauts complete refuelling operation from Progress 2.

23 Salyut 6 cosmonauts photograph the Crimes, the Caucasus, the southern Urals and the lowland shores of the Caspian Sea, Kazakhstan and the Central Asian Republics.

25 Skylab is restored to "low drag" orientation with its small end facing the direction of flight.

25 Viking 2 Orbiter is shut down after orbiting Mars 706 times. Spacecraft ran out of attitude control gas the previous day and JPL controllers commanded the transmitter 'off' at 2.02 a.m. EDT. (*Viking Orbiter 1 and both Viking Landers continue to function well almost three years after they were launched. Ed.*).

26 GEOS 2 reaches definitive station in geostationary orbit at 6 deg E.

27 Cosmonauts aboard Soyuz 29/Salyut 6/Progress 2 complete another technology experiment during which the furnace temperature reaches 1,100 deg C.

27 *Novosti* reports that two capsules containing 47 grams of semi-conductor alloy, crystallised out in the Salyut 6 'Splav' furnace and brought back by the Soyuz 30 international crew, were handed over by Institute of Space Research in Moscow to the Polish Academy of Sciences after preliminary examination by Soviet scientists. Further work on the sample will be carried out in Warsaw.

28 *Novosti* gives orbit of Soyuz 29/Salyut 6/Progress 2 as 328 x 346 km x 51.6 deg; period 91 min. Internal temperature is 20 deg C; pressure 770 mm.

29 Salyut 6 cosmonauts photograph Salsky experimental area in the region of Rostov which contains a wide range of different agricultural crops.

29 At 6 hrs 57 min (Moscow time) cosmonauts Vladimir Kovalyonok and Alexander Ivanchenko open the hatch of Salyut 6's transfer compartment to begin EVA lasting 2 hr 5 min. Space walk included changing equipment on outside of Salyut 6 by Ivanchenkov who anchored himself to the work station. His activities were photographed by Kovalyonok using a colour TV camera. Cosmonauts wore "a new type of semi-rigid space suit designed to ensure several hours of autonomous work in space." They used special tools to dismantle material from the outside of the transfer hatch, including a block with ampoules of bio-bolymers and polymers, and optical and other materials used in spacecraft construction. The cosmonauts installed "radio-sensitive plates" to measure radiation. They also inspected the micrometeroid detector and reported that no major impacts had taken place.

31 *Novosti* reports that USSR and France will conduct new joint space equipment in 1979 called Arcad 3. Soviet and French instruments will be installed in Intercosmos satellite "to study phenomena in the ionosphere and magnetosphere including the Northern Lights."

August

2 Progress 2 unmanned freighter is detached from Salyut 6/Soyuz 29 at 7 hrs 57 min (Moscow time)

[Continued on page 395

By C. A. Cross

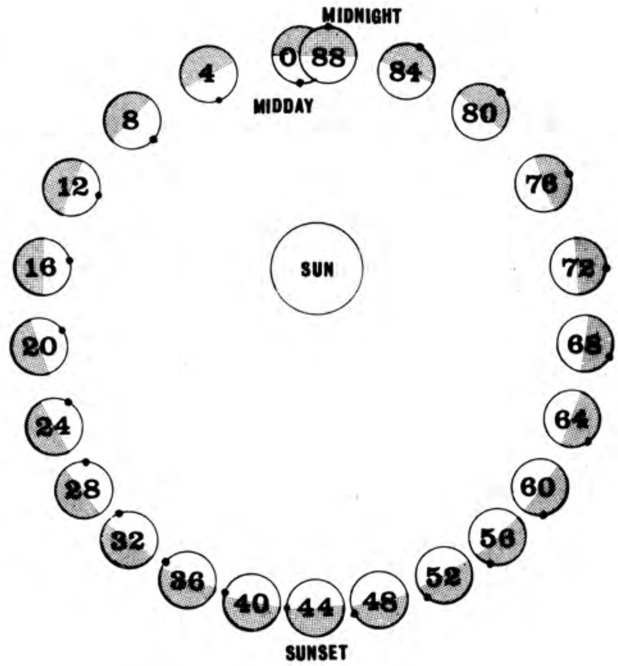
Introduction

Mariner 10 was launched on 3 November 1973, into an orbit which took it inwards towards the Sun to rendezvous with Venus. There it used the gravitational field of Venus to slow its movement round the Sun still more so that it followed an elliptical path cotangential with Mercury's orbit near aphelion, and timed to meet Mercury at that point. After first encounter it would have taken more than two of Mercury's years to return to the cotangent point, so missing any further rendezvous. By using Mercury's gravity, as had been done with Venus, the orbital period of Mariner 10 around the Sun was adjusted to exactly 175.938 days, so that a further encounter with Mercury could take place. The vehicle made this encounter and, in fact, survived in working order for a third encounter, which enabled important measurements to be made of the planet's magnetic field Thereafter,an inactive Mariner has continued its biennial rendezvous with Mercury.

During its 17 months of active life, Mariner 10 spent 17 days in planetary encounters, though only 17 hours were close enough for high-resolution pictures to be made.

Mercury rotates on its axis in 58.646 days, and takes 87.969 days to go once round its orbit. Thus it spins exactly three times in two of its years. Fig. 1 shows how this 3:2 spin orbit coupling results in a day which is two years long, and exposes longitudes 0° and 180° to the sun at alternate perihelion passages. Thus at two year intervals the same hemisphere is illuminated, and this is why, with encounters at two year intervals, the same hemisphere was observed at all three of them.

Fig. 2 shows the detailed circumstances of the three encounters as seen from the direction of the Sun. At the first encounter Mariner 10 caught up with Mercury, approaching from below the ecliptic plane and moving inwards towards the Sun. From point A the view was a crescent, tilted to show the South Pole. As it approached Mercury the crescent narrowed rapidly until Mariner 10 entered occultation at B. It then emerged from occultation and crossed the plane of Mercury's orbit at C. Thereafter, the crescent view widened rapidly to a gibbous disc at D. Because Mariner flew by the dark side of the planet a curved diagonal strip right across the planet was never visible.



The second encounter trajectory was parallel to the first but much closer to the Sun. At closest approach (point E) Mariner 10 was still well below the orbital plane. Thus, from E, the view was a gibbous disc with the south

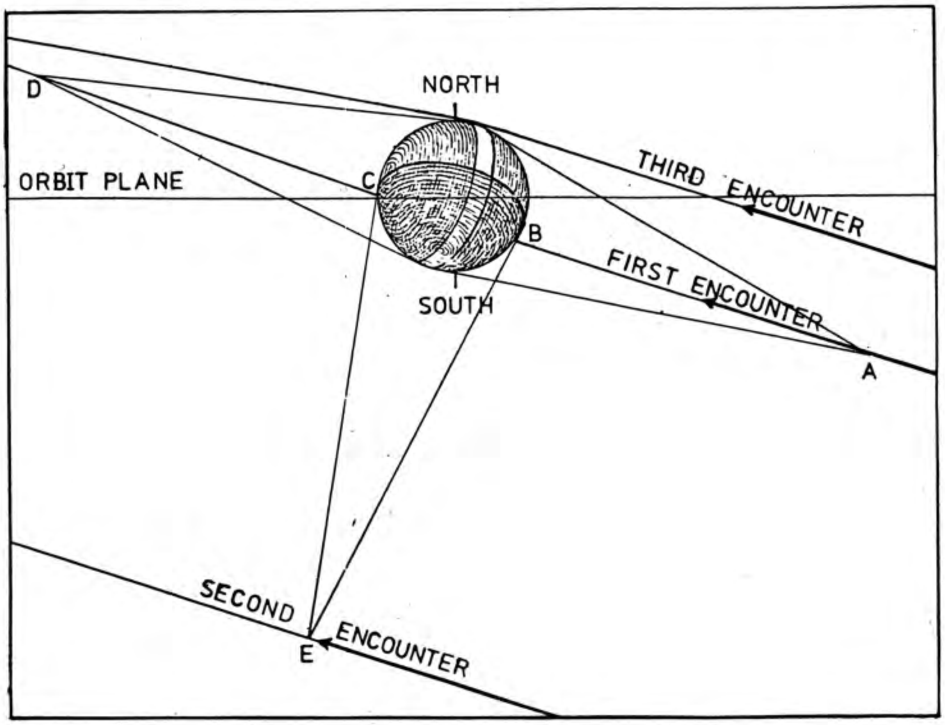


Fig. 1. *top right,* Mercury shown at intervals of four Earth days from one perihelion passage to the next, 88 Earth days later. Zero longitude is marked by the dot.

Fig. 2, *right,* details of the three Mariner 10 encounters with Mercury, showing the areas photographed during encounters 1 and 2.

pole in the centre of the terminator, leaving the northern end of the strip missed at the first encounter still unseen.

The third encounter trajectory was very similar to the first, coming even nearer to the planet at its closest approach at high northern latitudes. The same area remained invisible.

During the approach and recession from the first encounter, when full resolution pictures were being obtained at 42 second intervals, the camer's field of view covered only a small section of the visible surface. The onboard computer was programmed to alter the camera aim between each exposure so as to build up an overlapping grid of pictures. Thirteen such mosaics were obtained, but the two immediately before and the two immediately after closest approach were incomplete, with isolated pictures giving really close-up views. Because Mariner 10 passed so close to the planet, approach and recession were almost along a line of sight, so successive mosaics show nearly the same view of the planet.

At the second encounter Mariner 10 was farther away, so there was no period of partial mosaics and no close-up views. During the whole of the near encounter the viewpoint changed steadily, and a series of mosaics were obtained covering the centre of the disc as successive areas came into view.

At the third encounter picture taking was limited to quarter frames because a breakdown of the Goldstone and Canberra receivers restricted reception to 22 kilobits per second. The opportunity was taken to obtain closeup views of areas of special interest, but no mosaics were possible – nor could they have covered any new areas not already seen,

Mapping the Planet

To make a map from the thousands of pictures taken one must first locate the positions of the features shown. In normal terrestrial mapping, features are located in relation to a grid of control points fixed by a careful survey on the terrain (the familiar Ordnance Survey triangulation points). This is not yet possible on Mercury, though M. E. Davies has established a net of control points by less direct methods. He has chosen 1328 small easily identifiable craters, distributed over the visible surface, and has worked out accurate and consistent latitudes and longitudes for them. His first step was to measure their positions on the 545 pictures which showed them. These image coordinates were related to the latitudes and longitudes by complex equations involving: (a) the radius of Mercury and its position and orientation in space, (b) the position of Mariner 10 and the direction in which its camera was pointing, and (c) the effective focal length of the camera.

All the position and orientation parameters were changing with time, while the values required were those at the instant of exposure for each picture. Since the three camera angles were not very accurately known, these and the latitude and longitude were treated as unknowns, giving a matrix of 4291 (2x1328 + 3x545) simultaneous equations. These were solved by an iterative method on a very large computer. The results of all these extremely complicated computations was a grid of control points located to within 10 km standard error in the southern hemisphere, deteriorating to about 25 km in the North Polar region.

The "Greenwich" of Mercury

International Astronomical Union Commission 16 defined the zero meridian of Mercury as the subsolar point at first perihelion passage in 1950. Now that abundant topographical detail is known it is desirable to relate Mercury's coordinate grid to its surface features. Davies has done this by selecting a tiny crater (Fig. 3) and assigning to it longitude 20°W. The Greenwich of Mercury could not be located on the zero meridian, because this was in the dark hemisphere at Mariner 10 encounter times. The name of the crater is Hun Kal. It is the Mayan for twenty, and was chosen because their numbering system was to base twenty.

Mapping Projections

The conventional Mercator and Polar Stereographic projections (Fig. 4) are not ideally suited to showing the single

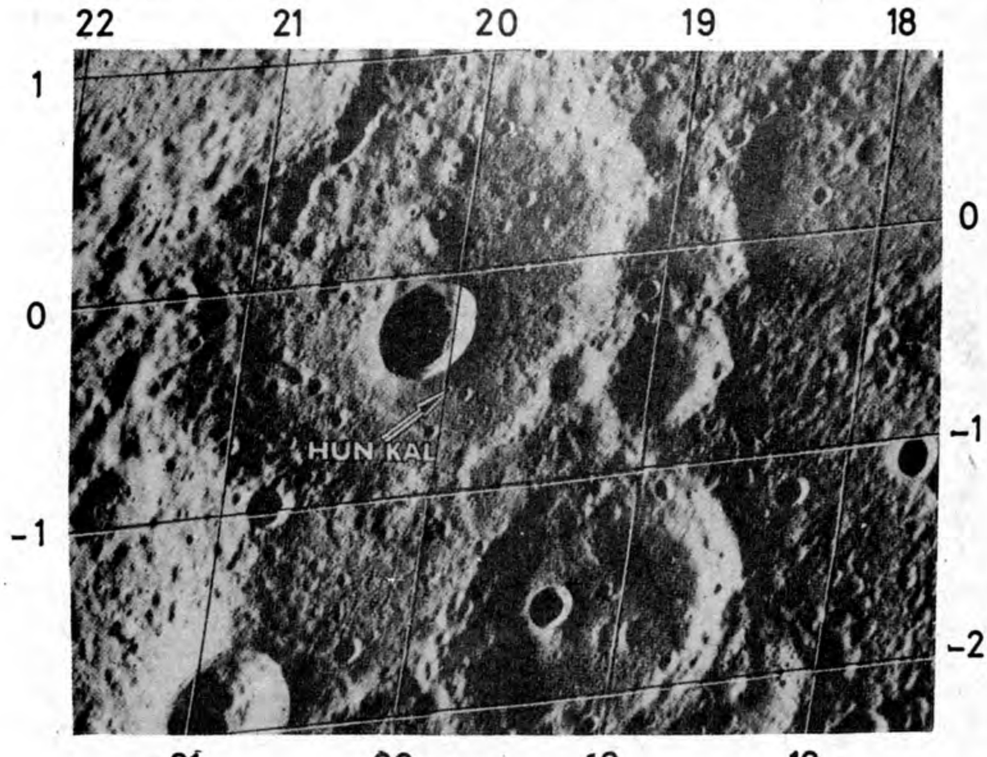


Fig. 3. Location of the 20° meridian of longitude on Mercury.

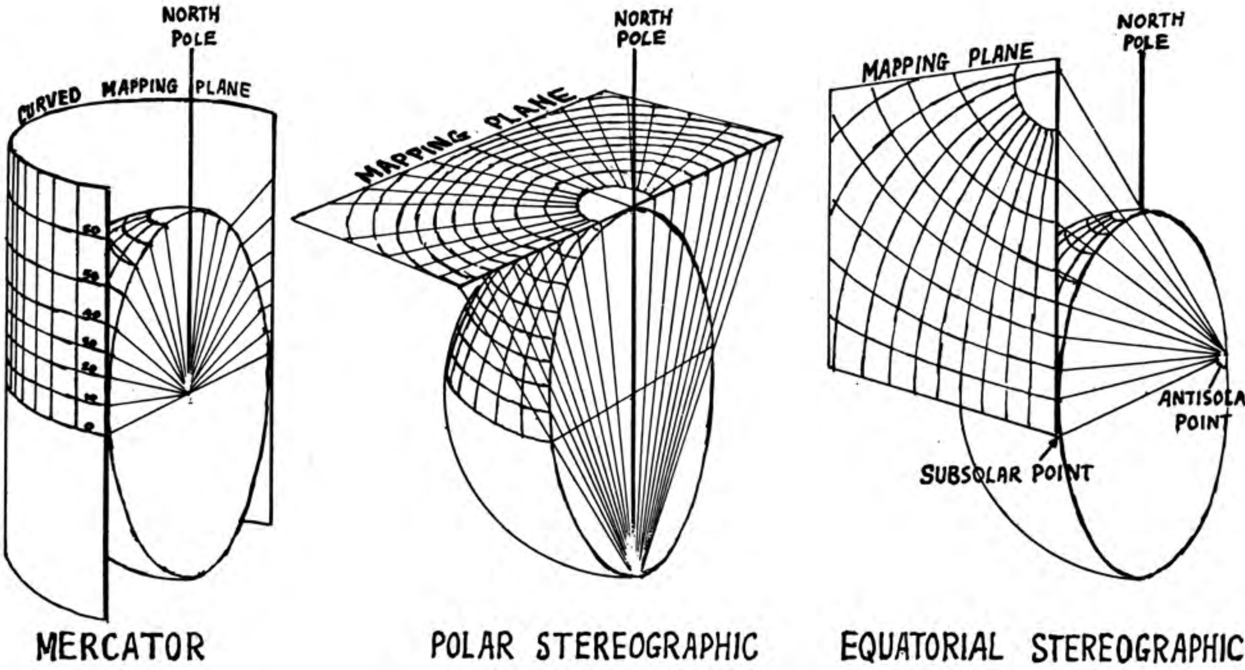


Fig. 4. The three conformal mapping projections shown diagramatically.

sunlit hemisphere of Mercury visible to Mariner 10. The little-used Equatorial Stereographic projection will make a single map of the whole illuminated hemisphere of the planet as a disc with the subsolar point at its centre, and the terminator (where the Sun is on the horizon for an observer on the planet) round its perimeter. Beyond the terminator the map extends into the unilluminated borders of the dark hemisphere.

Like the Mercator, this projection is conformal, which means that shapes and directions are preserved undistorted on the map. Circular craters are shown as circles everywhere on the surface. Again, like Mercator, the scale is variable, being doubled at the terminator. This is well suited to the portrayal of the increased detail brought out by the low Sun angles in these regions. Natural lighting has been reproduced on the maps, with all the shadows pointing directly away from the subsolar point. This has the advantage that the maps correspond exactly with the pictures, which is not so for maps with conventional illumination from the west.

Drawing the Maps

Maps of Mercury were drawn using a simple charcoal and stump technique with Rowney "Charcoal" No 1020 Medium pencil, and a range of rolled paper stumps to smudge and blend the charcoal. The control points were first plotted, and then the outlines of major craters were drawn in. Areas of shadow were next filled in, and finally the topographical details were developed using the stumps.

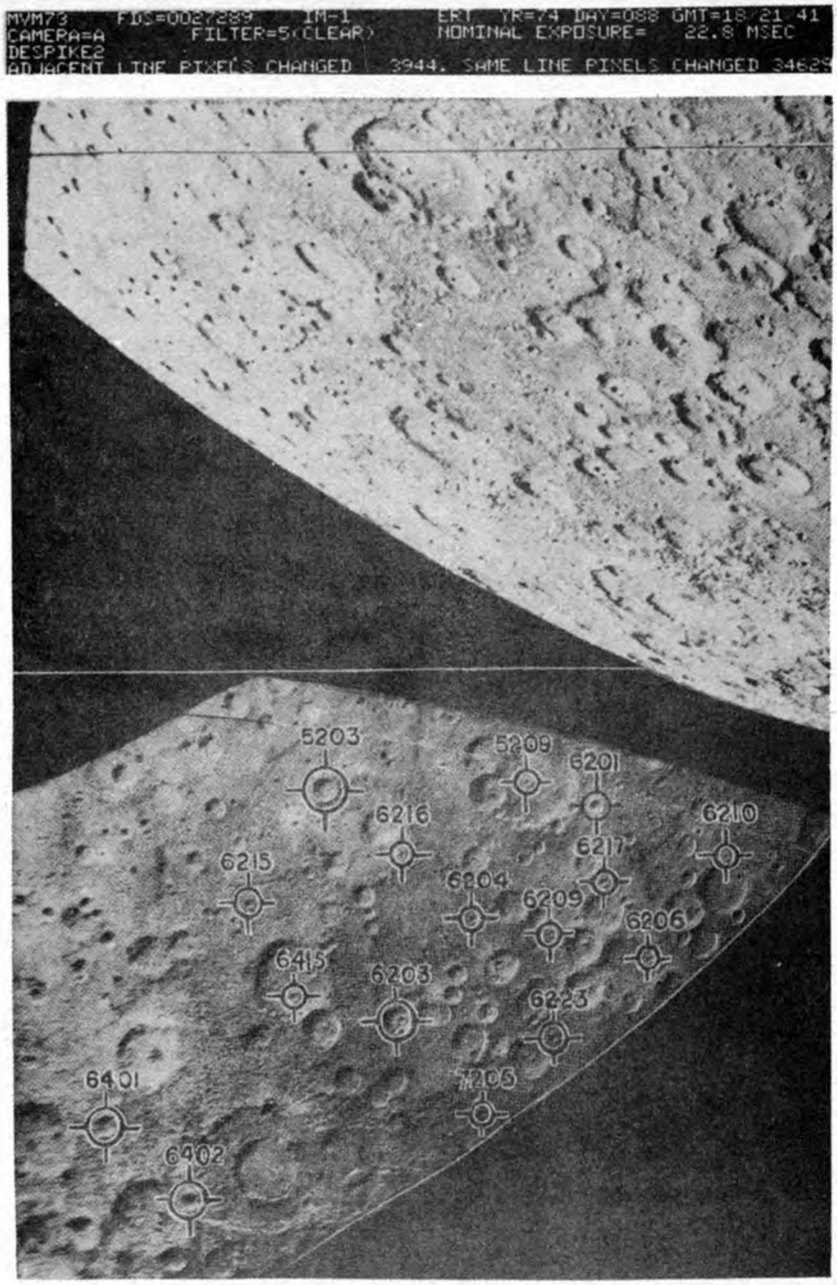
For many of the pictures, computer produced orthographic projections were available (Fig. 5) which gave great help in ensuring the accuracy of transposition. The details were filled in, always working from the maximum discrimination versions of the original perspective pictures, which retain most detail. The result of this work is illustrated by the reproduction of the map of the North West Quadrant (Fig. 6).

The North West Quadrant

The topography of this quadrant is dominated by the 1,350 km diameter Caloris Basin, whose centre lies beyond the terminator at 30°N, 195°W. Caloris is named because it lies close to longitude 180°, one of the two longitudes where the Sun assumes a temporary retrograde motion during the two-year long day. The Caloris Basin is similar in size to the Lunar Imbrium basin. Considerably less than half the floor is illuminated, but this part shows no sign of an inner concentric mountain ring (such as is seen in Mare Orientalis). Instead, the floor is strongly marked with a mainly concentric pattern of ridges and cracks unlike anything seen in the Lunar Mares. The ridges are somewhat similar to Mare wrinkle ridges, and appear to have been formed before the cracks, which pass through the ridges in many places. The cracks range in width from a maximum of 9 km down to the smallest width resolvable (about 700 m). They appear to be only a few hundred metres deep, with flat floors. Thus they resemble Lunar rills or graben. If so they indicate that the floor of the Caloris Basin is the only substantial area of the crust which has been under tension.

The whole of the Caloris planitia is a shallow basin, but because the edge is only between 5 and 10 km higher than the middle it is convex upwards, as may be seen from the way it is illuminated. The Caloris Mountains form an irregular blocky scarp standing a further 2 km above the edge of the plain. There is a 185 km wide gap separating the Northern and Southern portions of these mountains, located between latitudes 24 and 30°N. In the NE portion a weak outer scarp develops 100 to 150 km outside the main scarp.

Beyond the mountains a well developed system of radial valleys and ridges extends for up to one diameter away from the basin. Individual valleys reach lengths of over 120 km and widths of 16 km. These valleys dissect and modify many of the craters in this region, which are therefore older than the *Caloris Basin*. Both the old craters and the radial valleys



Left, **Fig. 5. The upper picture is FDS 0027289, taken during first encounter approach and showing the limb region at 85°S, 90°W. The lower picture shows the same view computer adjusted to an orthographic projection with sixteen control points marked in.**

Right, **Fig. 6. The North-west Quadrant of Mercury.**

have been flooded in some areas by lavas which have formed smooth mare-like plains, with well defined ghost craters. In other areas the surface is more hummocky and usually at a higher level, and may well represent a mantling with partially molten material ejected from Caloris itself. On this complex topography there is a sprinkling of younger craters with fresh rims and well developed ejecta sheets and fields of secondary craterlets.

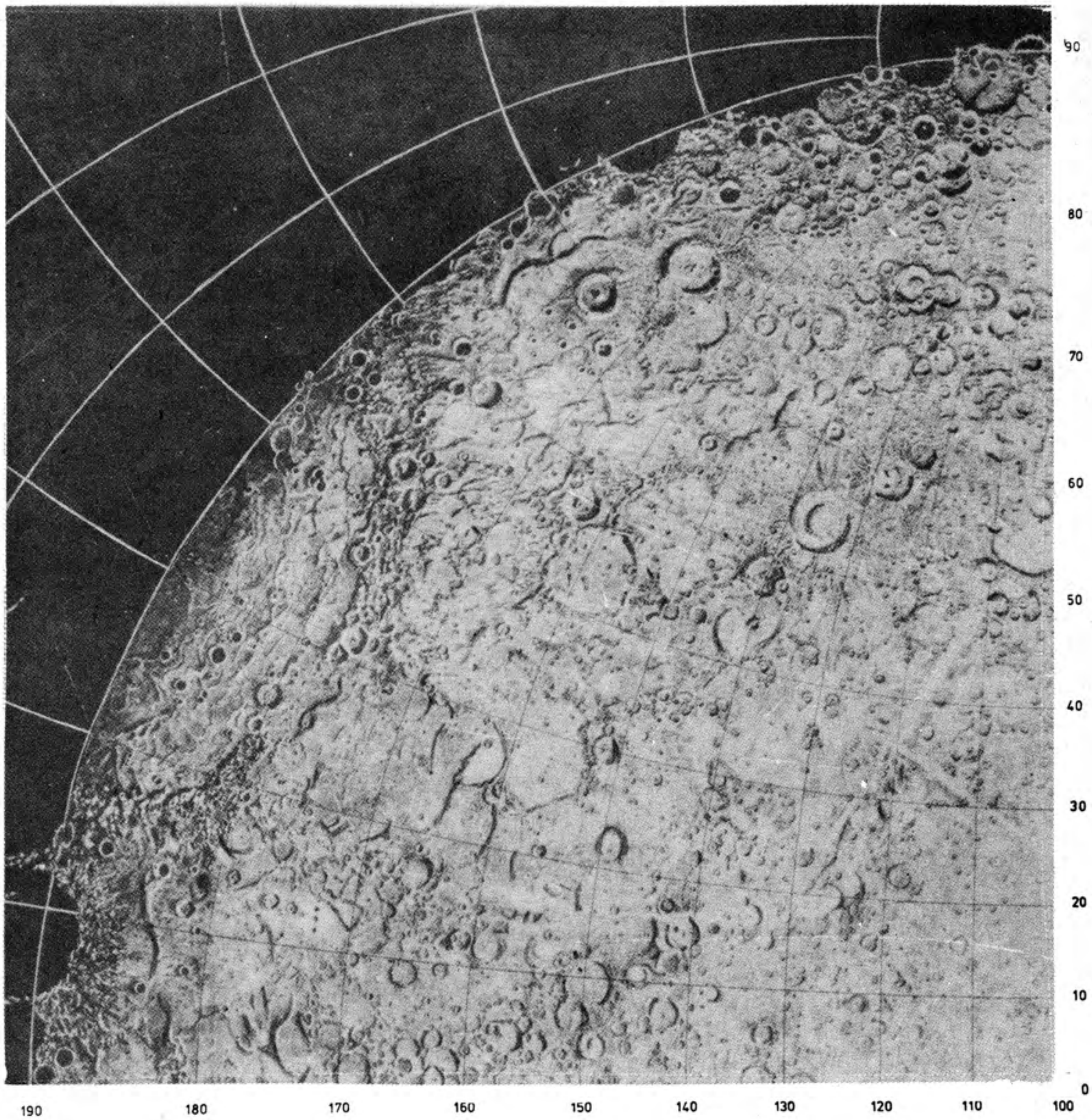
There will be much speculation about the exact way in which this enormous and complex structure was formed. It seems unlikely that impact alone could have produced the immense volumes of magma which cover the surrounding smooth plains (there is radar and thermal evidence that these extend right round the unilluminated side of the basin). Thus a reasonable view is that what we see now is the remains of a gigantic impact event which have been extensively modified by subsequent extrusive vulcanism.

Beyond about 1,000 km from the rim of Caloris its destructive effects die away, and the topography grades into cratered plains, which are the main terrain unit in the other quadrants. An exception is the area which lies around the antipodal point to the Caloris basin (Fig. 7). The general topography here has been christened by geologists "Hilly and lineated". It comprises a preponderance of positive relief features in the form of disconnected hills 5 to 10 km wide and 0.5 to 1.5 km high. The crater rims themselves seem to have been broken up in this way. Because this topography is only found in this restricted area it has been suggested by Schultz and Gault [1] that it may have been formed by seismic effects from the Caloris event.

The North East quadrant contains four prominent ray craters, counting the close pair in Planitia Sobkou as a single centre. The map shows that the peculiar curved ray seen to the south and east of these in more distant views is actually made up of a number of straight segments, but the origin of the prominent NNE component remains a puzzle.

Thus all the pictures and maps show clearly that Mercury has a very Moonlike surface, with differences in scale attributed to the stronger gravity. This concentrates the ejecta sheets and the secondary craterlets more closely around the

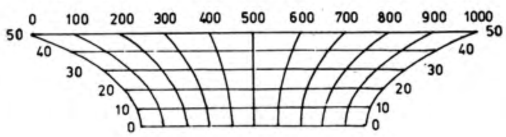
MERCURY



The North-west Quadrant of the Illuminated Hemisphere.

Equatorial Stereographic Projection.

Scales in Kilometres for distances in Cm from subsolar point



primary than on the Moon. It also causes the transition from plain bowls to craters with central peaks, and of peaks into central mountain rings, to take place at smaller diameters than on the Moon.

One striking feature not found on the Moon is the planet wide occurrence of ridges, which are believed to be compression thrust faults. Fig. 8 shows the magnificent Discovery Scarp, the middle third of which extends across the bottom of the picture. It intersects the 50 km crater Rameau, right centre, and then an unnamed 30 km crater, extreme right. The maximum difference in level across the scarp reaches 3 km, and the way in which it passes through the two craters indicates that it must have been of tectonic origin, and not a lava flow front. A smaller parallel scarp passes South of the 130 km crater Schevchenko, and extends through the SW wall onto the floor of the 120 km

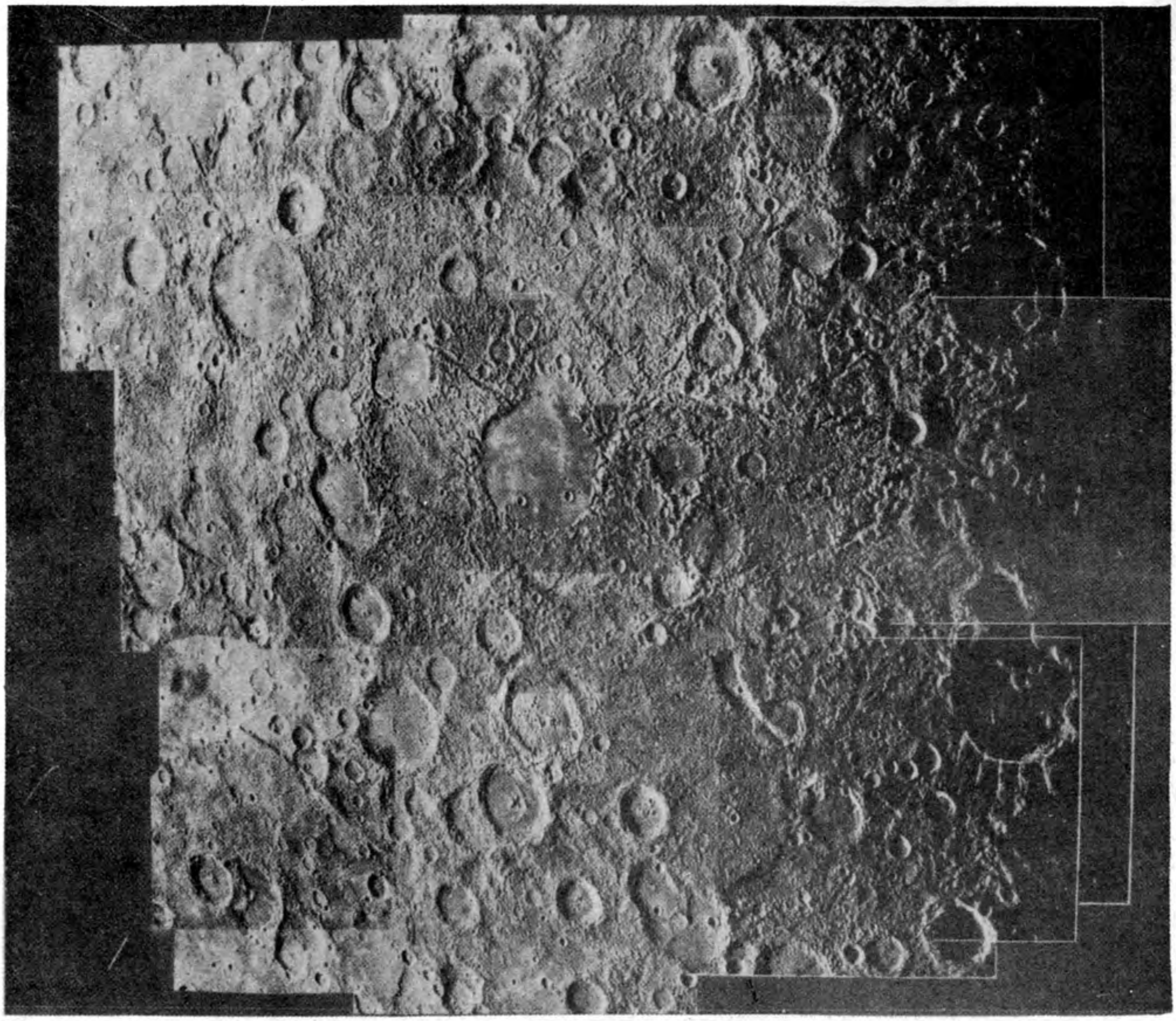


Fig. 7. Computer photomosaic of the region of hilly and lineated terrain centred at 30°S, 15°W, antipodal to the Caloris Basin.

diameter Africanus Horton. The crater chain extending diagonally across the top L corner originates from the crater Khansa, whose Eastern wall is just visible (L centre). Similar immense thrust faults are to be found over most of the visible surface (except the Caloris Basin), and this wide distribution supports the view that they were formed by contraction of the core of the planet perhaps arising during differentiation.

Scientific Measurements

Mariner 10 carried several scientific experimental packages in addition to the TV cameras. They may be conveniently divided into three groups:

(a) Ultra-violet Spectroscopy

Mariner 10's search for an atmosphere was based on U.V. spectroscopy in the wavelength range 300 to 1,300 Angstroms. In this region most gases absorb strongly at certain resonance frequencies, producing dark absorption lines analogous to Fraunhofer lines in the visible spectrum. The irradiated gas is also luminescent at these same characteristic wavelengths. Both effects were used in the attempt to detect a Mercurian atmosphere.

The occultation spectrometer attempted to measure the absorption of solar U.V. as the Sun entered and emerged from occultation by the planet during the first encounter. At this time the sunlight was passing tangentially to the surface through any atmospheric layer. The instrument accepted beams of direct sunlight through collimation pinholes, split these beams into spectra by a glancing incidence plane diffraction grating, and measured the U.V. flux at four wavelengths centred on the absorption bands for helium, neon, argon and krypton. No absorption of solar U.V. by these noble gases was detected. Since a 10% reduction in intensity would certainly have been noticed this result puts an upper limit on the pressure of these gases of 10^{-9} millibars. A similar negative result was obtained from the occultation of radio signals transmitted from Mariner 10 to the Earth, both with respect to detection of either a neutral atmosphere, or an ionosphere.

Mariner 10's Airglow U.V. Spectrometer was designed to detect the very faint light emissions from gases which are being excited by either U.V. radiation or electron bombardment. The principle is the same as the occultation spectrometer, but because the intensities are so much less than direct sunlight an elaborate system of sixteen slotted colli-

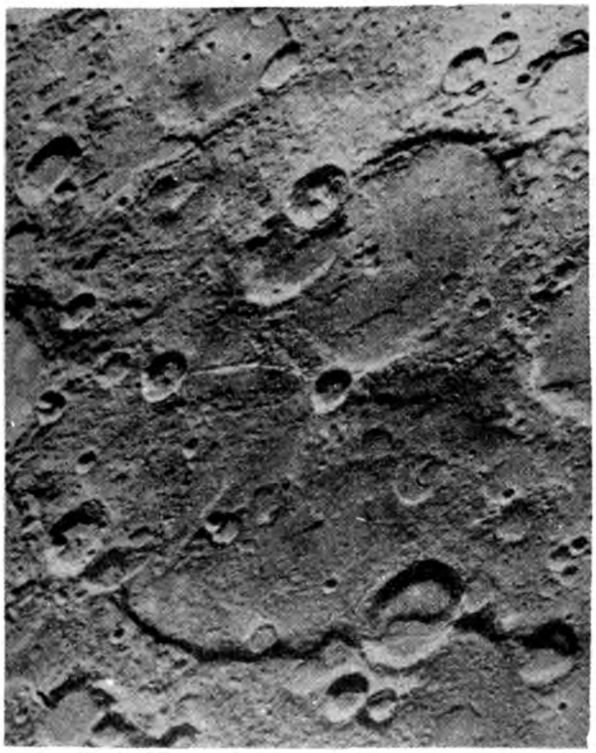


Fig. 8. The Discovery Scarp.

mation plates was used to admit sufficient light whilst defining a slit shaped field of view with the required spatial resolution. Ten channel electron multipliers located in a spectral band from a concave diffraction grating measured intensities at the emission wavelengths for helium, neon, argon, hydrogen, oxygen, and carbon dioxide. The main experiment scanned through the terminator into the dark hemisphere, to see whether any U.V. emission could be detected from atmospheric layers still illuminated by the Sun. In the event airglow emissions were detected for helium, neon, and argon. The measured intensities correspond to a pressure of 5×10^{-12} millibars of helium, about 1/200th of the smallest pressure detectable by the occultation spectrometer. Light emissions were detected from the night hemisphere during occultation, indicating that the gases were being excited by electron bombardment. Thus we know that Mercury has auroral displays in its night skies, though these may be very faint in the visible region.

(b) Infra-red Radiometry

Mariner 10's radiometers were capable of measuring surface temperatures down to -200°C with an accuracy of about ½°C. They were essentially the same as those flown on Mariners 6, 7, and 9 to Mars, modified to operate at the lower intensities and longer wavelengths expected from the dark hemisphere of Mercury. Two separate radiometers were used, one to measure at 12 micro-metres for the warm regions, the other at 45 micro-metres for the cold hemisphere. They comprised two 25 mm reflecting telescopes and thermopile junctions mounted side by side looking into a diagonal mirror. The mirror was turned by a stepping motor so that the telescopes viewed in succession an internal calibration surface at known temperature, empty space, and the surface of the planet. This calibration sequence enabled an absolute measurement of the infra-red brightness temperature to be made for a 1° field of view, which covered an area on the surface varying between 40 and 90 km in diameter during the first encounter traverse.

The scan across the dark hemisphere showed that during the first half of the 88 day long night cooling was only marginally slower than on the Moon, consistent with the presence of a moonlike layer of insulating silicate dust at least some tens of centimetres thick. During the second half of the scan however the surface was found to have cooled far less, suggesting the presence of a large scale region of enhanced thermal conductivity. This could be due either to a thinner insulating layer, or to exposure of large boulders or outcroppings of rock which are not blanketed by dust. This part of the scan lies to the Southwest of the unilluminated part of the Caloris Basin, and may represent the thermal properties of lava plains corresponding to those seen to the East of the basin.

(c) The Magnetic Environment

Mariner 10 was equipped with a magnetometer to measure both the interplanetary and any local planetary magnetic fields. It had plasma science instruments to measure the solar wind, and charged particle telescopes to measure higher energy particles. Since the magnetic environment continues between the planets this group of instruments, unlike those used only at planetary encounters was kept in operation during the whole flight.

The magnetic fields were measured by two triaxial fluxgate magnetometers carried on a glass reinforced plastic (glass epoxy) boom to remove them from the vehicle's own local field. This advanced type of magnetometer consists of three mutually perpendicular measuring coils, which enable the strength and direction of the external field to be reconstructed from the measured components. The magnetometers performed perfectly during the whole flight, and the direction and strength of the external fields encountered was measured with great accuracy.

When the first encounter results showed the completely unexpected presence of a planetary magnetic field strong enough to deflect the solar wind and to form a magnetosphere, the third encounter was planned to check these results by flying as close to the planet as possible, with the point of closest approach near the North pole. The predictions of the positions of the bow shock and the magnetopause, and of a fourfold increase in field strength at closest approach, were completely borne out at the encounter. Thus we now know that Mercury has a magnetic field which is well described by a centred dipole of moment 5×10^{22} gauss cm^3 oriented within 12° of the normal to the orbit plane. This dipole gives field intensities on the surface varying from 350 gamma, at the equator to about 700 gamma at the poles. This compares with some 30,000 gamma field strength on the Earth.

Measurements with the plasma science and charged particle instruments correlated and supported the magnetometer results. The solar wind, blowing steadily outside the bow shock, was excluded from the magnetosphere. This had its own quite distinct population comprising a very cool plasma sheet around the polar regions, and much more energetic plasma along the magnetic equator. The whole system forms a close match to a scaled down version of the Earth's own magnetosphere.

The Internal Structure

We know from simple consideration of the high overall density of 5.45 that Mercury must have a large iron core. The magnetic measurements strongly suggest the further conclusion that some part of this core must be fluid, and generating the external magnetic field in the same way that the Earth generates its own much stronger field.

Thus we see that although Mercury is like the Moon on its surface, its interior is more Earth-like. Mars is now known from the Viking results to be seismically very quiet, and we can readily accept that it may not have either a fluid core or a significant magnetic field. This leaves Venus in an anomalous position. It is large and dense enough to provide a fluid core, but Mariner 10 did not detect a magnetic field at its encounter with the planet. The reason may be that the spin period of 243 days compared with Mercury's 58 is just too slow, or perhaps Venus is just undergoing magnetic reversal at this epoch. Before Mariner 10 only Jupiter and Earth were known to have their own magnetic fields. Mercury extends this privilege to a much smaller and slower rotating body, and its further study could cast much light on the phenomena of planetary magnetism.

The Future

The prospect for further probes to Mercury is not good, for NASA has more important priorities than the further examination of a very moonlike body inconveniently near the Sun. We are, however, left with one unknown hemisphere. It is possible that some information may be obtained from the Orbiting Astronomical Observatory, which can work at high resolution from outside our atmosphere. It is even possible that some results might be obtained from the Earth's surface by the use of interactive optics which correct atmospheric disturbances. We shall not however be able to map the missing hemisphere in the detail we have between longitudes 10 to 190° until another vehicle visits the planet for this purpose.

REFERENCES

1. Schultz, P. H. & Gault, D. E., *Seismic Effects from Major Basin Formation on the Moon and Mercury*, NASA Tech Memo X-62, pp. 338, 1974.

SUCCESS OF HEAO 1

NASA's HEAO 1, the first in a series of unmanned observatories designed for the study of celestial X-rays and gamma rays, has been officially declared a success. The spacecraft's primary objective was to obtain highly detailed experimental data on astrophysical phenomena by measuring the size and location of X-ray sources in the sky, and by determining the intensity and time variation of these sources.

This objective has been accomplished and, according to Dr. Noel W. Hinners, NASA Associate Administrator for Space Science: "X-ray sources barely visible in older studies stand out clearly in HEAO 1 data. The faintest sources are one million times weaker than the first X-ray star discovered 15 years ago.

"Many of the HEAO 1 sources are distant active galaxies. A map of the diffuse X-ray background shows that a hot thermal plasma extends beyond our Galaxy and may spread throughout the Universe. This is of major importance in understanding the early evolution of the Universe."

HEAO 1, launched in August 1977, carries four sets of experiments, provided by the Naval Research Laboratory, Goddard Space Flight Center, Smithsonian Astrophysical Observatory, Massachusetts Institute of Technology, California Institute of Technology and the University of California at San Diego, all under contract to NASA.

With few exceptions, the experiments returned excellent data during the six-month baseline mission operations programme, which was completed last February. (An extension of the HEAO 1 mission was recently authorized to permit a second scan of the celestial sphere and to broaden scientific participation through a Guest Investigator Program). The HEAO 1 data will increase three or four times the number of known X-ray sources.

"In addition to the normal scanning manoeuvre, which is the primary operating mode of HEAO 1, the observatory points at specific celestial objects for detailed investigations," Dr. Hinners remarked. "To date, more than 80 of these pointings have occurred."

The secondary objective of the HEAO 1 mission was to demonstrate that the spacecraft was capable of supporting the experiments on board for six months. This objective has also been met. The spacecraft, designed and built by TRW, Inc., of Redondo Beach, California, has achieved or surpassed all design specifications. The initial activation of the spacecraft went exceptionally well and the performance, since that activation has been excellent.

The rate gyro assembly, which was produced under a sub-contract to Bendix Corporation, and which encountered technical problems resulting in the initial HEAO launch delay, has performed extremely well. Drift rates almost an order of magnitude below what were expected have been experienced during the mission.

More information on new X-ray sources and their accurate locations is emerging as the analysis of HEAO 1 data proceeds. Dr. Hinners said: "Accurate location of X-ray sources has resulted in increased success in identifying the optical counterparts to the X-ray sources. This, in turn, will enable astrophysicists to study the radiation mechanisms in far greater detail than would be possible with X-ray data alone."

The second HEAO satellite, designed to study in detail interesting sources pinpointed by HEAO 1, is scheduled to be launched in November 1978. The third of the series will be launched in 1979. The programme is managed for NASA's Office of Space Science by the Marshall Space Flight Center at Huntsville, Alabama.

U.K. PARTICIPATION IN GEOS

Three British University Groups from University College, London, Sheffield and Sussex are actively engaged in experiments of an international collaborative programme designed to study the Earth's magnetosphere from data received from ESA's geostationary satellite GEOS 2. The satellite was launched from Cape Canaveral, Florida on 14 July at 10.43 hours GMT. Its payload includes a UK experiment known as S-302, designed to study plasma, prepared by the Mullard Space Science Laboratory (MSSL) of the University College of London. This experiment consists of two suprathermal plasma analysers furnished by MSSL to form an integrated set of particle and field measuring instruments.

Two other UK groups are collaborating with other European groups to obtain data from the S-300 experiment. The group from Sheffield University is studying waves of turbulence in the hot plasma at the geostationary orbit, while a second group from Sussex University is looking at compressed wave data.

Both MSSL and the group from Sheffield University are using the Science Research Council's Rutherford Laboratory IBM 360/195 computer for data processing.

MISSIONS TO SALYUT 6

By Gordon R. Hooper

Continued from June issue, p. 229

PART 3

Soyuz 27

On 10 January 1978 at 12.26 (all times expressed in GMT), the Soviet Union launched Soyuz 27, callsign PAMIRS, carrying a two man crew. The commander was Lt. Colonel Vladimir Dzhanibekov and the flight-engineer Oleg Makarov. Dzhanibekov was making his first flight, having previously served as back-up to Alexei Leonov, commander of the Soyuz 19 ASTP mission in July 1975. Makarov was making his third flight, having previously flown as flight-engineer on both Soyuz 12 in 1973, and the ill-fated "April 5 anomaly" in 1975.

The flight programme provided for a link-up with the Salyut 6/Soyuz 26 space station, where the two crews would conduct joint research. Soviet space chiefs were unusually explicit in their advance announcement of the proposed link-up, indicating that they were confident of success.

Soyuz 27 was placed in an initial orbit of 223 x 202 km (139 x 126 miles) x 51.7°. The Salyut station, which had passsed over the Tyuratam/Leninsk space centre some 17 minutes before the Soyuz 27 launch, was in a 343 x 338 km (213 x 210 miles) x 51.5° orbit. By the 5th revolution, Soyuz 27 was in a 296 x 247 km (184 x 154 miles) orbit, according to NORAD. At least one additional manoeuvre was conducted prior to the docking on revolution 17.

Dzhanibekov and Makarov checked their onboard systems and established contact with MCC, and then exchanged greetings with Romanenko and Grechko onboard Salyut 6. They were said to be feeling happier now that their comrades were about to join them. Soviet space chiefs admitted that the forthcoming docking and joint research programme would be "an important and complicated operation".

In a pre-launch press conference, Makarov told reporters at Tyuratam/Leninsk that the two crews working together on the one station would not only double their capacity but would give the space expedition a qualitatively new dimension.

On 11 January, Soyuz 27 was reported to be in a 302 x 257 km (188 x 160 miles) x 89.9 min x 51.6° orbit, and closing on the Salyut. Dzhanibekov first reported seeing the space lab at a distance of 1½ km (0.9 miles), and his next report came at a distance of only 300m (328 yards) when the station's lights could be clearly seen. At a distance of 10m (11 yards) he reported that he could clearly see the docking mechanism, and that the spacecraft had entered the Earth's shadow. A successful docking then took place at 14.06. The docking operation may well have been completely automatic, as the Soviets omitted all the usual references to the Soyuz commander having taken manual control at the distance of approximately 100m (109 yards) from the Salyut.

During the whole of the docking operation, the Salyut crew of Yuri Romanenko and Georgi Grechko retired to the safety of the Soyuz 26 ferry craft. In the event of any mishap, such as an excessive closing speed and dangerously hard docking, leading to rapid depressurization of the Salyut, the Soyuz 26 vehicle would have been able to undock and carry the crew to safety.

With the docking completed, the crew returned to the Salyut to welcome their comrades onboard. The two crews first checked the docking interface for leaks before opening the connecting hatches. In a recording later shown on Soviet TV, Romanenko and Grechko could be seen eagerly pulling Oleg Makarov through the hatch, followed closely by Dzhanibekov. The event took place some three hours after docking.

Cosmonauts in the space complex Soyuz 27-Salyut 6-Soyuz 26: Georgi Grechko, Vladimir Dzhanibekov and Oleg Makarov.

Novosti Press Agency

The four cosmonauts immediately celebrated their success by toasting each other with cold cherry juice squeezed from tubes, laughing loudly and hugging one another. The newcomers had brought with them copies of *Pravda*, letters, books, gifts from friends and relatives, and research equipment. *Soviet News* pointed out that this was only the second space "mail-drop" in history, the first time being in 1969, during the Soyuz 4/5 mission.

Tass reported that "for the first time in the history of cosmonautics, a manned scientific research complex has been created in terrestrial orbit consisting of an orbiting station and two spacecraft." This was "a major achievement of Soviet science and technology, opening up new and broad vistas for the further utilization of outer space in the interests of science and the national economy." *Tass* went on to announce that the four men would remain in space together for 5 days, during which time "a number of joint scientific-technical studies are to be conducted." The Soyuz 27 crew would then return to Earth in the Soyuz 26 spacecraft.

Problems of Double Docking

General Vladimir Shatalov, director of cosmonaut training, stressed the engineering nature of the new Soyuz/Salyut mission. "The sixth Soviet orbital station," he said, "is, in many ways, an experimental space vehicle. New technical ideas will be tested during its flight. In particular, it is fitted with two docking units which permit much more

effective expeditions. It opens up the possibility for stations to operate with two transport vehicles, a more reasonable and economical conduct of operations to replace the crews and the provision for additional scientific equipment and food stocks for the expedition."

Commenting on the link-up, Konstantin Feoktistov said that it was another step toward the creation of "sophisticated engineering complexes in terrestrial orbit." These would carry out scientific and "natural-economic tasks." Of the docking itself, Feoktistov commented that since it was the first time that a spaceship had had to dock with two already docked spacecraft, some people had feared a "switch-effect," i.e. that a break could occur between the first and second craft. Calculations had revealed, however, that this would not happen.

With the redesigning of the Salyut to incorporate a second docking unit, and the attachment of a second ferry, the dynamic characteristics of the station were considerably altered, affecting its centre of mass and moment of inertia. This led to concern that dangerous stresses and strains would result from any docking and subsequent increase in the length and mass of the space complex. It was therefore decided to conduct experiments to determine the dynamic loads on the space complex.

The experiments, entitled "Resonance," began with MCC beaming a metronome signal to the station and ordering the cosmonauts to run or jump with the rhythm using their treadmill. MCC were looking for possible resonances, or vibrations, which might lead to fatigue failure in the structure if overlooked for a long time.

In an extreme case, according to *Soviet Weekly*, any such fatigue failure could lead to external elements such as antennae or fuel cells breaking away, or even to depressurization occurring at the docking interfaces between Salyut 6 and any ferry craft attached to it.

Resonant frequencies are taken into account by the design teams, but the history of engineering has shown that unexpected resonances may arise in a structure with disastrous consequences. So the design team took no chances, as the resonant frequencies would alter with each change in the configuration of Salyut 6, as other craft docked with it.

The running and jumping of the cosmonauts sent vibrations through the entire 30 m (33 yards) long, 32 ton Soyuz 26/Salyut6/Soyuz 27 complex. Instruments in various parts of the structure then registered the dampening of these vibrations. The design team were apparently well satisfied with the results.

On 12 January, the four cosmonauts began work at 05.00. During the day they conducted medical and biological research, technical experiments, and inspections and check-ups of the systems of the space station and Soyuz craft. They also took photographs and film of the Soviet Union, and held TV sessions. The Salyut was in a 367 x 334 km (228 x 208 miles) x 91.3 min x 51.6° orbit.

'Cytos' Experiment

However, much of the day's work was in connection with a joint Soviet-French experiment called "Cytos." Dzhanibekov and Makarov had brought with them containers full of micro-organisms in a Soviet-designed thermostat. These were transferred to the French-designed "Cytos" instrument, with the aim of studying the effect of spaceflight and radiation on the cell division of micro-organisms.

A detailed explanation of the Cytos experiment later appeared in *Moscow News*, (28 January 1978), following the completion of the Soyuz 27 crew's mission:

In the early part of January 1978, several dozen protozoa of *Paramecium* made an unusual trip from Paris to Moscow, then to Tyuratam-Leninsk, and finally to Salyut 6, courtesy of Soyuz 27. It was the first time that a joint Soviet-French biological experiment had been carried out onboard a Salyut.

For a week, a group of French biologists led by Prof. Hubert Planel of the University of Toulouse were in Moscow at the Institute of Medico-Biological Problems (USSR Ministry of Public Health) for joint work with their Soviet colleagues.

According to Prof. Yuri Nefedov, Deputy Director of the Institute, the aim of the Cytos experiment was to help answer the question: "Can Man adapt completely to the conditions of outer space?" This could only be answered when enough data had been obtained on the space reactions of a living organism at the cell level. "Every organism, including the most complex one, consists of cells, and their division is the basis of life. So we want to know how a cell divides under excess strain and vibration, weightlessness and radiation."

"Two sets of protozoa—the French scientists were interested in the *Paramecium* and the Soviet biologists in *Proteidae*—were used in the experiment. We gave each cell a separate "room", in something that looks like the plastic containers for shampoo. It wasn't easy to isolate a cell from a culture and to seal it in a plastic capsule. Prof. Planel and his group did this tough operation with real skill. As soon as a cell divided, the daughter cells were put in two different "rooms." Some capsules went into space, the others were kept as a control.

The protozoa were sent into orbit in a state close to anabiosis—at a temperature of 8°C (46°F), when the metabolism is inhibited: the cell is kept alive, but cannot divide. Once Dzhanibekov and Makarov got them onboard the space station, the capsules were placed in another thermostat at a temperature of 25°C (77°F). The cells then began to divide. What the cosmonauts had to do was to inhibit this development after exactly twelve hours had gone by, using a special mechanism for the job. In another twelve hours they put another series into action. So in four days we obtained eight consecutive generations—eight instant pictures of cell division.

"Our French colleagues were very pleased by the enthusiasm with which the team of four cosmonauts onboard the orbital station responded to their requests. Now the capsules are back on Earth, in laboratories," he concluded.

Prof. Planel also gave details of the experiment: "We in France designed and built the Cytos thermostats that can maintain the permanent temperature necessary for normal and stable cell development. We also had to prepare the *Paramecium* culture. Soviet scientists took on the second part of the work, developing the methods to study another culture—*Proteidae*. So this is the first experiment in space biology in which we could investigate the influence of weightlessness on two different unicell organisms in absolutely similar conditions.

"As soon as the cosmonauts brought back the capsules we and our Soviet colleagues started some hair-splitting operations (the *Proteidae*, for instance, is 1.5 microns long and 1 micron wide). We'll look at the superthin objects through an electron microscope and try and distinguish the changes in their structure, biochemical composition and genetic apparatus."

Changing Cosmonaut Couches

On 13 January, Dzhanibekov and Makarov carried out research into the blood distribution system. The results of this experiment were expected to help find ways of easing the cosmonauts adaptation to weightlessness. In addition, they removed their individually moulded "couch liners" from the descent module of Soyuz 27 and exchanged them for the ones in the Soyuz 26 spacecraft. These moulded liners were "specially-designed individual equipment which

made it easier for the cosmonauts to endure the g-loads of launch and landing." Pressure suits and other individual equipment were also transferred to Soyuz 26.

Dzhanibekov, a radio-electronics expert, carried out an inspection of the Salyut's electrical systems, which had, by this time, been in operation for over a hundred days. During the day, the four cosmonauts made preparations for a further "Resonance" experiment.

On 14 January, the four cosmonauts conducted Earth observations work and conducted biological experiments. In the afternoon, they carried out the "Resonance" experiment.

On 15 January, an experiment was carried out to discover ways of "optimizing the methods of control of complex space systems" which involved orientation and stabilization of the Soyuz 26-27/Salyut 6 complex. During the afternoon, they completed the Cytos experiment, and transferred the biological specimens to Soyuz 26.

Dzhanibekov and Makarov also carried out a systems check on the Soyuz in preparation for their return to Earth, and continued transferring instruments and materials used in their experiments.

In the morning of 16 January, the two men reported readiness for the return to Earth. Calculations in private correspondence with Ralph F. Gibbons indicate that undocking occurred at approximately 08.27, although no official time has been released. As the Soyuz 26 capsule slowly moved away, Yuri Romanenko and Georgi Grechko watched from onboard the Salyut station. Dzhanibekov reported that he could see the firing of the instrument module's engines.

During the next communications session, he reported that the Soyuz was oriented correctly, and that everything was going according to plan. An hour later, the Soyuz spacecraft swept over South America, across the Atlantic, over Africa and then re-entered over the Caucasus Mountains. According to NORAD data, the Soyuz made between 2 and 3 revolutions after separating from the Salyut.

Once the capsule's radio-blackout had ended, radio communications were re-established with MCC. Dzhanibekov reported that the messages were coming through loud and clear, and that the g-forces were decreasing. The descent was very smooth, and they had established radio contact with the helicopter recovery crews.

A *Tass* bulletin released at 12.30 announced that the descent capsule had touched down 310 km (192 miles) West of Tselinograd, in Kazakhstan. Again, no official time was given for the landing, but another calculation by Ralph F. Gibbons, using a set of formulae devised by Phillip S. Clark, indicated that the touchdown occurred at approximately 11.46. The two cosmonauts emerged from the capsule smiling broadly, and looking healthy, to be greeted with embraces, flowers, applause and the traditional Russian gift of bread and salt given to travellers.

On 17 January, the Grechko-Romanenko team were given a day of rest, two days ahead of schedule, following their intensive 5 days of work with the Dzhanibekov-Makarov crew. They listened to a special programme by a leading Soviet sports commentator on a recent Soviet-Canadian ice-hockey match. They also talked over the radio to Dzhanibekov and Makarov, who gave a full description of their landing.

Importance of Orbital Stations

Assessing the flight on Radio Moscow, Alexei Leonov pointed out that the Soviet Union is concentrating its manned space programme on orbital stations. This meant that one important problem had had to be solved—how to ferry crews to and from permanently operating stations. The Salyut stations had facilities for *six*, so sometime in the future six cosmonauts could work on one.

He also noted that experts in different fields of science could be ferried to the station for special research and experiments. That meant, he concluded, that space research could be conducted on a wider scale and more effectively.

Also on the 17th, *Novosti* reported an article by Vladimir Shatalov which had appeared in the newspaper *Air Transport*. He wrote that the creation of the space complex was a new step in space exploration which opened up new prospects. He mentioned that it was now possible to ferry supplies, scientific apparatus and samples as well as crews. Having four men onboard a space complex was important because it meant that the scientific instruments could be used far more efficiently over 24 hours.

Earth Resources Observations

On 18 January, the Grechko-Romanenko crew began the Raduga experiment, which lasted for two days. This involved photographing the Earth with the MKF-6M multispectral camera, which had been tested onboard Soyuz 22. (see *Spaceflight*, February 1977, p.61.) The camera had been modified and adapted for use on long term orbital stations.

During the Soyuz 22 mission, the work was, according to *Novosti*, purely scientific. However, the aim of the Salyut 6 operation was divided into 1/10th scientific purposes, 9/10th practical Earth resources. Each sequence covered a territory of 220 x 165 km (137 x 103 miles). Radio Moscow reported that photographs obtained in 5 minutes from space contain as much data as pictures that can be collected by aerial photography over two years. Ground studies on the same scale would take 80 years to complete.

On 19 January, they continued their work on the Raduga experiment. They photographed a vast area in Soviet Central Asia looking for possible mineral deposits. They also took photographs of the German Democratic Republic for use by GDR scientists, the designers of the MKF-6M. An East German team of scientists led by Prof. Hans Fischer was present in MCC during the experiment. Prof. Fischer described the work of the cosmonauts as "excellent."

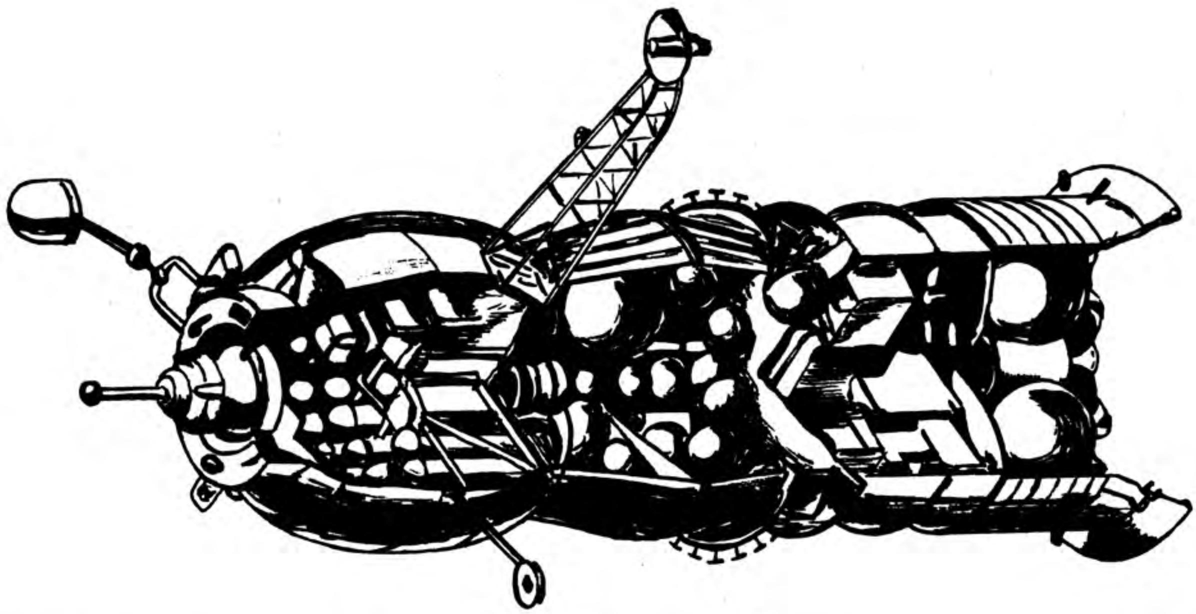
Progress Cargo Ship

On 20 January, the Soviet space programme took another large step forward with the launch of an unmanned re-supply ship to Salyut 6. The spacecraft, given the somewhat unimaginative title of Progress 1, was launched from Tyuratam/Leninsk. No launch time was given, but calculations in private correspondence by both Phillip S. Clark and Ralph F. Gibbons indicate that the launch time of Progress 1 was 08.24, a figure which should be correct to approximately ±2 minutes or so. This calculation seems to be confirmed by a *Flight International* report which quoted a launch time of 08.23.

Tass called Progress 1 "an automatic transport spacecraft," and reported that it would deliver fuel, experimental apparatus and life support material to the Salyut 6 station. Radio Moscow reported that "the present launching of an unmanned transport craft of the Progress type marks a new stage in space exploration. Spacecraft of this type will be able to carry much more cargo than manned Soyuz craft. They are also cheaper, as they are not intended for return to Earth."

Radio Moscow added that the Progress craft was based on the repeatedly tested Soyuz. Its docking system was identical, but all descent and landing systems had been eliminated, resulting in considerable weight-savings. Progress 1 was placed in an initial orbit of 262 x 194 km (163 x 121 miles) x 90.2 min. x 51.6°. The operation was code-named "Earth-orbit" by MCC.

The new spacecraft has no solar panels, and has an inde-



Internal detail of the Progress 1 Cargo ship. Drawing based on *Pravda* (8 February 1978) illustration.

pendent flight time of 8 days. As part of an orbital complex, however, it can remain in space for up to one month.

The Progress spacecraft had been designed to free orbiting stations from operating limitations due to a lack of consumables. Externally, Progress is longer than the normal Soyuz because an extra instrument section has been added to the aft end of the vehicle to accommodate new systems required to perform a tanker mission. The Progress is 8m long (8.7 yards), whereas the Soyuz is 7.5m (8.2 yards).

Design changes involved in converting the basic Soyuz vehicle to the Progress spacecraft resulted in the new craft weighing 7005 kg (15,444 lb) compared with the normal Soyuz weight of 6577 kg (14,500 lb). The new spacecraft also has a cargo/fuel load of 2295 kg (5060 lb) with 998 kg (2200 lb) of that weight comprising fuel and oxygen for resupplying Salyut stations.

The normal Soyuz orbital module has been reconfigured as a cargo module that can carry 1297 kg (2860 lbs) of dry supplies. A framework inside the module is used to hold cargo in place, with the small items packaged together in large containers. The larger items were attached directly to the inside framework of the cargo module, normally with quick release latches. Bolts are also used, but these require only a quarter turn with a spanner to speed unloading by the cosmonauts.

The docking system on the Progress is more complex than on the normal Soyuz. Additional hydraulic and other plumbing connectors were installed to enable the Progress/Salyut conduits to mate for refuelling operations. The docking unit has a warning system to make sure that the plumbing and docking latches connect properly between the Salyut and Progress.

The Soyuz Descent Module has been replaced by a unit containing four propellant tanks and several other spherical nitrogen and compressed air tanks. The Progress uses the same thrusters developed for Soyuz spacecraft—fourteen 10 kg (22 lb) and eight 1 kg (2.2 lb). The automatic attitude control and thermal control systems differ quite substantially, however, from the Soyuz.

Progress also carries three external beacons to enable the Salyut crew to locate the vehicle during rendezvous and docking. There are also two externally mounted TV cameras—one positioned to view along the longitudinal axis of the spacecraft, and the other at right angles. The Progress transmits rendezvous data to MCC and direct to the Salyut during approach, and the cosmonauts can then actively participate in manoeuvering the spacecraft for an automatic docking.

Also on 20 January, *Novosti* reported that the French National Space Research Centre in Toulouse had received the Cytos experiment containers. Once the French scientists had completed their analysis, they were to meet with their Soviet colleagues to discuss the results, following which their conclusions would be published.

On 21 January, Yuri Romanenko and Georgi Grechko spent the day checking the Salyut's systems in preparation for the docking with Progress 1. Meanwhile, on Earth, Dzhanibekov and Makarov returned to Star Town, where Konstantin Feoktistov thanked them for the excellent job they had done in testing new spacecraft equipment. Alexei Leonov said that during their five days in orbit, Dzhanibekov and Makarov had done an enormous amount of work both in testing the new equipment and as members of the first joint crew of an orbital complex.

Writing in *Moscow News*, Valery Kubasov said that the Dzhanibekov-Makarov team should be designated by a new term—"visiting crew", even though these visitors didn't come as idle guests, but for work.

He said that it was conceivable that an emergency situation might arise on a Salyut station, when a visiting crew might be the only way out. So it may be considered that Dzhanibekov and Makarov carried out the first space rehearsal as visitors and as repair workers, and as a possible replacement crew and a possible rescue crew. "For me as a cosmonaut," he said, "this experiment has resulted in considerably added possibilities for human performance in outer space."

A science correspondent of *Soviet Weekly* reported that following the success of the Soyuz 26/27-Salyut 6 link-up, it would be possible "to keep orbiting laboratories of the Salyut type continuously manned for years by changing crews at regular intervals. The double docking had also established, in principle at least, the feasibility of joining two or more orbital stations together, to make a much larger complex."

In the same article, Konstantin Feoktistov discussed how

orbital stations could provide a more extensive base for space activities. "For example," he said, "the development of power plants able to transform solar energy and transmit it to Earth seems a promising line of research. These would be huge structures which could be built in a fairly low orbit, like that of Salyut 6, before being transported into a geostationary orbit about 36,209 km (22,500 miles) up, to serve a particular area of the Earth's surface."

On 22 January, the cosmonauts completed final preparations for the docking with Progress 1. MCC decided that the cosmonauts did not have to retreat to the safety of their Soyuz spacecraft as had happened during the Soyuz 27 docking. In the event of an emergency, they would have been able to switch on the Salyut's engines and moved away from the Progress craft. In the case of small deviations from the planned docking approach, the cosmonauts would have been able to make corrections.

They watched the docking operation on a TV monitor inside the space station, and first spotted the Progress tanker at a distance of about 10 km (6 miles). It appeared as a dull luminescent spot, slowly turning into a bright star until gradually its contours came into clear view.

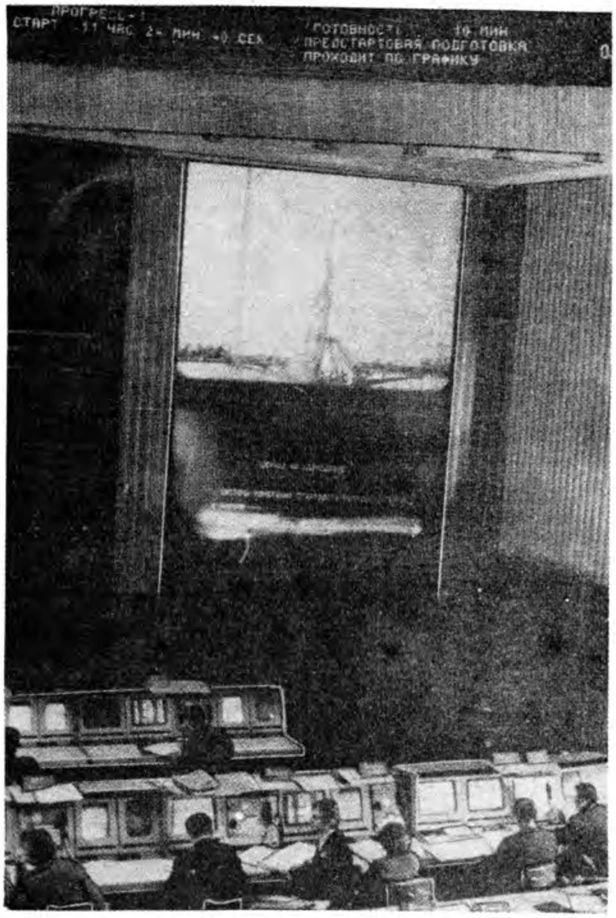
The docking operation was controlled by two separate teams at MCC. One team continually checked the Salyut systems and the other the Progress systems. Substantial manoeuvres had been conducted on revolutions 4, 17, and 31 before the final approach on revolution 33. Progress successfully docked with Salyut 6 at 10.12, the first time that an unmanned supply craft had docked with a manned space-station. (The principle had been tested with the unmanned Soyuz 20 craft, which docked with the previously manned Salyut 4 in November 1975).

Tass reported that Progress 1 carried "fuel for the Salyut power units and other cargo–equipment, apparatus and materials for life support of the crew and for scientific exploration and experiments."

According to *Novosti*, the success of Progress 1 showed "that Soviet space technology has mastered the problems of automatic space cargo transport. The flight of Soyuz 27 had already proved the practical feasibility of a shuttle service, replacing the crews in orbital stations." The mutual search and approach manoeuvres, together with the actual docking, were carried out completely automatically by means of radio-technical equipment and computer devices onboard Progress 1.

Interviewed by *Moscow News*, Alexei Yeliseyev the Salyut 6 Flight-Director said: "Being able to send cargo to orbital space stations opens up a lot of new avenues. First the cosmonauts can receive new materials they need for research, whether it be camera film, items for biological experiments, instruments, etc. Second, we can now send up devices and equipment which the station itself needs for functioning. By doing this, we make the onboard systems more reliable, and we'll be able to replace equipment that gets 'tired' during the flight. Third, there is no way a station can operate without irreplaceable expenditures. The station loses a certain amount of its atmosphere when waste is jettisoned through airlocks or when the cosmonauts go for a spacewalk. And air is very precious in orbit. You also need fuel to be able to correct the orbit and to manoeuvre the orbital complex in space; getting fuel supplies was a real problem, but we've solved it. Progress 1 carried up the extra fuel.

"Finally," he said, "the crew needs a lot of other things if they are to function properly in orbit–food, water, hygienic devices, underwear and medicines. Sending up cargo by unmanned craft is the best way of prolonging the active functioning of orbital research complexes. Once the crew has unloaded the automatic craft, they can pack used equipment, empty containers and waste into it, and then the craft will be a means of disposal.



Flight controllers at the Kalinin control centre during launch preparations for Progress 1.

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There are still a lot of problems to be solved in space exploration, but we're over the hump of one of them: making sure supplies get to, and communications are kept with, orbital stations. The Salyut-Progress complex is a really big stride forward in space exploration."

On 22 January, Grechko and Romanenko made their first entry into Progress 1. MCC allowed the cosmonauts "on their urgent request" to open the connecting hatches and collect parcels and letters. Under the flight programme, the crew were supposed to have a day of rest. They talked with relatives over the radio and watched a videotape recording of a concert on their TV monitor. They also spoke to a prominent nature journalist, and told him that they had observed the snow in Southern Russia turning dark and melting, heralding the coming of spring.

On 23 January, the crew continued unloading the Progress ferry. Radio Moscow reported that Grechko and Romanenko were the first men to master the profession of "space docker," a skilled job requiring great precision. On board the ferry were heavily stressed exercise suits to help the crew maintain muscle and circulatory functions to a higher degree.

An *Aviation Week and Space Technology* report stated that a Soviet spaceflight would soon take place involving Czech as well as Soviet crewmen, according to Vaclam Bumba, director of the Astronomical Institute of the Czechoslovakian Academy of Sciences. Bumba said "joint cosmic flights of Czech and Soviet cosmonauts are the next

stage in the programme of Socialist countries (researching space)." Bumba did not specify when the mission would take place, but the Intercosmos cosmonauts had been training for some time at Star Town.

On 24 January, the cosmonauts in orbit had a morning of active rest, doing physical exercises and checking onboard systems. In the afternoon, they began preparations for the refuelling operation, checking that the fuel lines were airtight, and that the fuel and gas systems were in order. An *Agence France Presse* report dated 24 January revealed that informed sources in Czechoslovakia (possibly those quoted in the *Aviation Week and Space Technology* article), were reported to have said that a Soyuz spacecraft with a joint Soviet-Czechoslovakian crew onboard was to be sent into space to join Salyut 6 within the next few days. The sources said that the Czech cosmonaut was a pilot.

On 25 January, the crew spent the day transferring materials from Progress 1, including water, food and the new exercise suits. At the request of scientists, they observed noctiluscent clouds over the South Pole, and Polar Lights over the North Pole.

Importance of Cargo Ships

In a *Novosti* report, Konstantin Feoktistov described the important role envisaged for cargo ships, and said that work on ships of the Progress type had virtually coincided with the start of the designing of orbital stations. "Even at that time," he said, "we were aware that in order to ensure the functioning of space stations over prolonged periods of time, both manned launchings and cargo flights would be necessary." Outlining the functions of a cargo ship, he said: "First of all, there are always specific materials which cannot be kept on board for long. For example, film. It deteriorates with time. Or biological objects – in some cases they cannot be delivered to the orbital station long before the start of an experiment."

"Some interesting idea may always turn up in the course of an extensive programme of orbital studies designed for a long period. But to carry out this idea may necessitate a new device. It is also probable that some of the units may fail: the station carries more than a thousand devices and many of them are subjected to intensive use. This means that replacements may be needed. Such cargoes are only part of the overall payload of the ship."

"It must also be remembered that the station has expendable materials. One of these is fuel – for making changes in the orbit of the station or its orientation. It is also necessary to replenish the stocks of gases that make up the artificial atmosphere. Occasional replacements of carbon dioxide absorbers and filters in the life support system are required. And, in addition, there are objects of purely everyday use necessary for normal life onboard, such as water for the shower unit, or linen."

"The daily average of such expendable materials amounts to about 30 kg (66 lb) per person. It can easily be calculated that on a sufficiently long flight their weight would amount to some tons, and with an increase in the size of the crew the expenditure of materials would, of course, grow to a corresponding degree."

Speaking of Progress 1, Feoktistov said that "it shares the basic design features of a Soyuz spacecraft, but for economy we made it as light and capacious as possible. The unit module has remained almost unchanged while the size of the instrument module has been increased. Special tanks for liquid cargoes and a compartment for dry cargoes have been added. The freight compartment is hermetically sealed so that, after docking, the cosmonauts can work in it to transfer cargo to Salyut 6."

"Because the power circuit and the layout of the spaceship substantially changed, the ship underwent a complete cycle of tests, including strength, vibration, and heat regime tests. Even such an operation as the stowage of the cargoes in the compartments has required a lot of effort since it takes a relatively long time to carry even a small number of things in space. So we have done our best to make it as easy as possible."

On 26 January, Grechko and Romanenko readied the Salyut's oxidant tanks for the refuelling process. They also replaced air filters in the life support system with fresh ones delivered by Progress 1.

On 27 January, the cosmonauts had a medical check-up, and doctors also studied them as they unloaded the Progress ferry. On 28 January, the space doctors reported that Grechko and Romanenko's physical condition had become practically stabilised, and such indices as pulse rate and blood pressure had returned to their normal values on Earth.

Soviet Weekly reported that further development work on Progress-type vehicles could lead to the construction of automatic cargo-vessels which could return to Earth and be used for repeated journeys.

On 29 January, the cosmonauts had another day of rest. They checked out the Salyut and Soyuz systems, monitored the scientific instruments requiring daily attention, such as the biological ones, held communications sessions with MCC, and underwent their routine medical checks. They then did physical exercises before doing the household chores and getting up to date with paperwork. They also talked to their families for over an hour, and listened to music over the radio. In the afternoon, they were allowed to continue studies of the Earth's surface, taking photographs of the Mediterranean and Mt. Etna, Europe's highest volcano.

On 30 January, their 52nd day in orbit, the two cosmonauts continued to unload the Progress. On the following day, they pumped compressed air into the Salyut, to replenish its supplies which had become depleted following Georgi Grechko's EVA. On 1 February, the two men moved used equipment from the Salyut, and loaded it into the Progress.

Salyut Refuelling

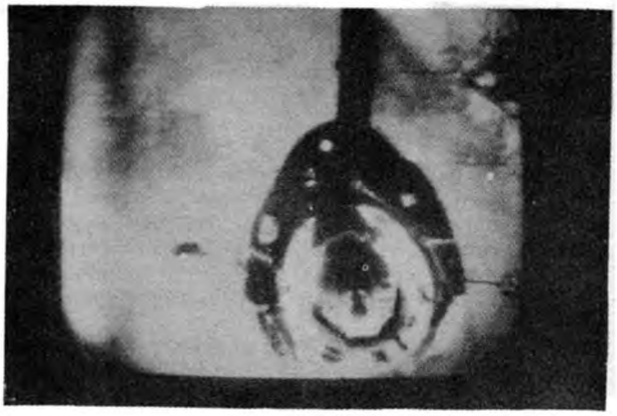
On 2 February, Yuri Romanenko and Georgi Grechko carried out the first-ever refuelling operation in space.

The procedure was complex. Salyut 6 has three oxidiser and three fuel tanks, each with a metal bellows, or accordion-type divider in the middle. When the tanks are full, the accordion is pressed flat against the internal wall of each tank. Nitrogen under pressure is then released from onboard cylinders to expand the accordion, forcing fuel into the engine system. The nitrogen is stored at 3234 psi, or 220 atmospheres.

At the time refuelling was due to take place, tank pressure was about 20 atmospheres. *Novosti* reported that the simple solution of providing the refuelling tanks of Progress 1 with even higher pressures to overcome the back pressure of the Salyut's tanks would have involved an unacceptable weight penalty in the freighter.

Equally it was not possible to generate assisting gravity forces by accelerating the Salyut/Soyuz/Progress complex in an appropriate direction without upsetting the flight plan. The most rational solution available was to reduce the pressure in Salyut's tanks by pumping back nitrogen into the storage cylinders before refuelling started.

This was done by using a newly designed 1 kw compressor, the design of which posed challenges to Soviet engineers because it had to operate with three phase alternating current. The Salyut, however, runs on a solar cell/battery electrical system that operates on direct current. An electrical converter was therefore added to the compressor to enable it to operate from the standard Salyut power system.



Progress 1 approaches to dock with Salyut 6.

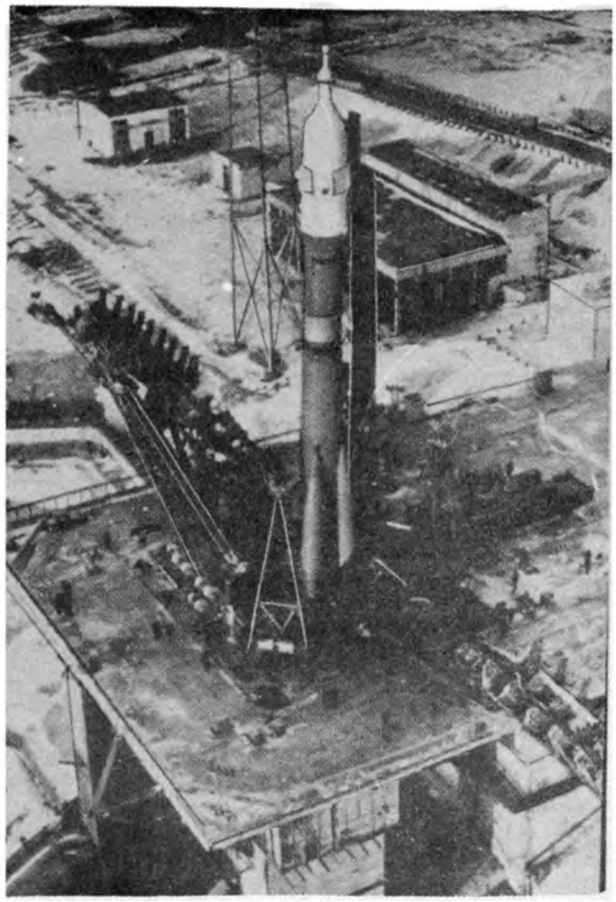
Photo: Michael J. Richardson

Operation of the compressor put a heavy drain on the storage batteries, so preparations for refuelling were staggered over six shifts, so as not to affect other systems requiring electrical power.

The compressor eventually reduced the nitrogen pressure in the tanks to 3 atmospheres, low enough for the Progress 1 pressure vessels to overcome, enabling refuelling to take place. Compressed nitrogen at 8 atmospheres was used in the Progress to pressure feed the new propellants into the Salyut. The fuel was transferred first, followed by the oxidizer. The fuel had been flushed with helium before lift-off to clear any dissolved gas.

At least two of the oxidizer and two of the propellant tanks on the Salyut can be refuelled by the Progress tanker. During the Progress 1 operation, one set of Salyut oxidizer and fuel tanks were still full and did not require replenishing. The Soviets apparently consider this third set of tanks a reserve, and it is not clear whether they can actually be refuelled in space. The Progress tanker is equipped with two oxidizer and two fuel tanks for resupplying the Salyut. The entire refuelling operation can be controlled by either MCC or the Salyut crew.

According to an *Aviation Week and Space Technology* report, the Soviets had made a fundamental change in the Salyut's rocket engine and fuel system by switching to pressure-fed from turbine-driven main engines and adopting a common hypergolic propellant for both the main propulsion and RCS engines. Prior to Salyut 6, both the Soyuz and Salyut propulsion systems operated in the same manner. In the reaction control system, hydrogen peroxide thrusters were used for attitude adjustments. The hydrogen peroxide was also used to drive turbines that pumped hypergolic oxidizer and fuel to the main propulsion system. In the main propulsion system, the propellants used were a form of nitric acid and a form of hydrazine. This arrangement required three sets of propulsion lines and tanks – one for the main engine fuel; one for the main engine oxidizer; and one for the hydrogen peroxide. The Soviets had not specifically stated that the nitric acid and hydrazine forms were being used on Salyut 6, but details emerging from the Soviet Union indicated that they had moved to a pressure-fed main engine and a hypergolic RCS instead of the cold-fire, hydrogen peroxide thrusters used on all Salyuts prior to Salyut 6. This change enables both the RCS thrusters and the main engines to use propellants from the same tanks, allowing much simpler and more effective orbital refuelling



Soyuz 28 on launch pad at Tyuratam. Near the pad are buildings not seen in previous photographs. This mission will be reviewed in the next part of this series.

Novosti Press Agency

operations than if hydrogen peroxide also had to be replenished.

The change to pressure-fed main engines for the Salyut means the Soviets are now using a much simpler and more reliable system than the turbine-driven system. Turbine-driven rocket engines are used in both US and Soviet launch vehicles, but the US has used pressure-fed in most, if not all, of its spacecraft propulsion systems.

To achieve this type of operation on Salyut, the Soviets had to design an entirely new internal tanking and propellant line fuel system, develop the pressure-fed engines, and develop the hypergolic thruster system for the vehicle, all this in addition to the major design changes to the aft section of the station to accommodate a second docking port.

Grechko's Space Record

Also on 2 February, Georgi Grechko set a new personal record for time spent in space. At 13.15, his time spent onboard the Salyut 4 and Salyut 6 stations equalled the 84 days 1 hour and 16 minutes record set by the Skylab 4 crew.

On 3 February, the two cosmonauts carried out the concluding stage of the refuelling operation. During the morning communications sessions with MCC, they reported that the preparatory operations for refuelling the station with oxidizer were being carried out in accordance with the

schedule. After checking for leaks, the cosmonauts punched instructions into the Salyut computer, and the refuelling operation began. The operation was carefully controlled and monitored by both the cosmonauts and MCC, and was completed by 09.00.

Dealing with Emergencies

A *Pravda* article at the beginning of February dealt with the "missing" eight hours of activity in space not usually mentioned in reports from MCC. The author, V. Zubkov, pointed out that the cosmonauts sleep for 8 hours and work for an 8 hour shift, leaving 8 hours regularly unaccounted for. He explained that much of this time is spent on eating, toilet, preparations for sleep, and so on. But sometimes, it is the time when emergencies are dealt with.

Before the Soyuz 27 crew arrived to join Romanenko and Grechko, one of the four voice communications transmitters broke down. The possibility of this happening had been foreseen, and acting upon instructions from MCC, the cosmonauts switched to a back-up unit.

Another emergency had MCC quite worried, according to Victor Blagov, the deputy flight controller. Following their spacewalk the cosmonauts closed the outer hatch of the transfer compartment, but telemetry received by MCC indicated that a vent valve, which allowed air to escape to depressurize the compartment, had remained open. This meant that no matter how much air was pumped into the transfer compartment, it would not be possible to pressurize it, as the air would simply be vented through the open valve. The cosmonauts could not, therefore, return to the main compartment of the Salyut.

MCC issued instructions for the cosmonauts to go ahead normally with the repressurization, and when they did so, the pressure began to rise, indicating that it had been a false alarm. It transpired that there had been a fault in a cable, which led to the wrong information being received. MCC thought the fault might be due to condensation, and were concerned that this might lead to short-circuiting or premature corrosion. The cosmonauts were therefore ordered to check for moisture in the electrical circuits, but their search proved fruitless.

On 4 February, the cosmonauts had another day of active rest, following the strain of the refuelling operations. They did physical exercises, talked to their families over the radio, and listened to a concert. In a TV session, they showed TV viewers how the Earth looked from an altitude of 350 km (217 miles). The Caucasus Mountains could be clearly seen, as could the Volga Delta and some parts of Siberia. During the day, the cosmonauts also carried out the 5th in a series of Resonance experiments.

On 5 February, following completion of the refuelling operation the cosmonauts had to bleed the flow lines to prevent any fuel or oxidizer from being accidentally sprayed in the vicinity of the station when the Progress undocked. This was done by using compressed nitrogen in Progress 1 to purge the fuel remaining in the transfer lines. Once this operation had been successfully completed, the Progress engines were switched on to make two corrections to the Salyut orbit. *Novosti* claimed the operation heralded the use of space tugs, to assemble the space stations of the future.

Soviet Weekly reported that the use of Progress 1 as a space tug resulted from a quick decision by Flight Director Yeliseyev to take advantage of fuel reserves left in the Progress craft. These reserves were due to the fact that only 3 flight corrections were necessary during the independent flight of Progress 1 prior to docking, instead of the 5 that had been planned.

In a TV session, Romanenko and Grechko revealed that they were missing the Earth. They said that they often dreamt of woods and rivers, and of going skiing. They reported that the Volga, Ural Mountains and Siberia were clearly visible from the station, although thick cloud cover was present further to the East.

Discarding Progress 1

On 6 February, at 05.53, Progress 1 undocked from the Salyut station. During the 15 days that the Progress tanker had been linked to the space station, the cosmonauts spent 12 shifts unloading the supplies. They also re-loaded it with used equipment, being very careful to maintain the proper centre of gravity in the spacecraft to facilitate a correct separation.

The undocking operation was controlled by the cosmonauts, and following separation, MCC took control. The spacecraft was allowed to drift some 13-16 km (8-10 miles) away from the Salyut and then MCC activated the back-up automatic approach systems. The Progress carried out a completely automatic approach without any assistance from the cosmonauts. Whether or not the spacecraft actually docked again has not been revealed by the Soviets.

The two cosmonauts had loaded the Progress with used water and food, filters from the station's oxygen regeneration systems, and scientific equipment no longer required onboard the Salyut. This led to several Press comments in the West about the Progress being "a cosmic dustbin!"

In order to allay fears of a repeat of the recent Cosmos 954 incident, Soviet space officials emphasized that the Progress would re-enter over a very remote area of the Pacific, sometime on 8 February. The official *Tass* line was that upon re-entry, Progress 1 would "cease to exist." However, Igor Bazhinov, a senior Soviet space programme official, interviewed on Soviet TV, indicated that some fragments might be expected to reach the ground.

Tass correspondent Nikolai Zheleznov reported that "the experiment in refuelling the orbital station and providing it with new scientific equipment is a practical response by Soviet engineers, technicians and cosmonauts to one of the main objectives in cosmonautics. It is a way to ensure a long life for orbital stations. The actual refuelling of the orbital station has been a brilliant engineering operation which will enrich the practice of world cosmonautics with valuable experience." Readers may like to be reminded of an article which appeared in *Spaceflight* July/August 1976, p.293, in which Peter Smolders interviewed Andrian Nikolayev. During the course of the conversation, Nikolayev outlined the entire Progress operation – nearly two years *before* the flight of Progress 1.

On 7 February, the cosmonauts carried out several medical experiments, studying the distribution of blood in weightlessness, and the effects of weightlessness on various muscle groups.

A report from East Germany suggested that a Czech military pilot, trained at the Yuri Gagarin Cosmonauts Training Centre, might become the first man from outside the US and the Soviet Union to fly in space. The flight (to Salyut 6) might take place on 27 February.

On 8 February, according to *Soviet News*, "in accordance with the flight programme, after completing operations on command from the ground, Progress 1 was oriented in space and its engine was switched on. As a result of braking, the ship was put into a descent trajectory, entered the dense layers of the atmosphere over a pre-determined area of the Pacific and ceased to exist."

Radio Moscow reported that "the descent trajectory was chosen in such a way as to rule out any harm that might be caused by the ship's debris on reaching the Earth. A Soviet tracking station in the Far East followed the ship's flight which terminated over an uninhabited area in the Pacific". Ralph Gibbons calculated that Progress 1 re-entered at approximately 02.54.

On 9 February, Grechko and Romanenko took more pictures of the Soviet Union "in the interests of the national economy" using the MKF-6M camera.

On 10 February, Radio Moscow reported that since Yuri Romanenko and Georgi Grechko began work onboard Salyut 6, Soviet TV had been carrying daily colour transmissions from orbit. The station then presented extracts from one of the more recent broadcasts, which began with Grechko "catching" a weightless pencil to make notes on a pad. He then began talking to the viewers: *"Hello everyone. Today marks the 150th birthday of Jules Verne, the remarkable French writer. There's hardly a person who hasn't read his books, at any rate not among the cosmonauts, because Jules Verne was a dreamer, a visionary who saw flights in space. I'd say this flight too was predicted by Jules Verne."*

Yuri Romanenko then elaborated: "A favourite saying of one of Jules Verne's heroes, 'motion within motion' applies well to this space laboratory. We're orbiting the Earth," he said "and at the same time we move around inside the laboratory. Our mechanisms are functioning well. They too are in motion inside the moving station. Modern science and engineering have of course left far behind Jules Verne's boldest thoughts and ideas. Planes have become commonplace, so have the radio and television that help us to keep in contact with the Earth."

"We all know," he continued, "that it's impossible to travel around the Moon in a shell fired from a Gun, but it's quite possible to carry out spaceflights aboard rockets and spacecraft. Flights of this kind have become part of our way of life. One of Jules Verne's characters went around the world in 80 days. Our space-lab covers the same distance in a mere 1½ hours. Since it was launched, the laboratory has made over 2000 circuits around the globe."

Soviet Space Endurance Record

On 11 February, at 00.39, the two men broke the Soviet national space endurance record of 62 days 23 hours and 20 minutes set by the Soyuz 18 crew in July 1975. The Soyuz 18 crew, Pyotr Klimuk and Vitaly Sevastyanov, spoke to Romanenko and Grechko over the radio and congratulated them on their feat. Radio Moscow reported that several American astronauts, including Skylab 4 crew-member Ed Gibson, had asked for their best wishes and congratulations to be conveyed to the Soviet crew.

A medical examination convinced the medical specialists that the two cosmonauts had attained what was described by A. Yegorov as "a state of stable adaptation to weightlessness."

During the day, Grechko and Romanenko continued their studies of the Earth's surface. They took pictures of glaciers in the Central Asian Mountains to determine their water potential. The data thus obtained, according to *Novosti*, would enable the scientists to forecast the flow of mountain rivers which could be used to feed irrigation systems.

The cosmonauts also studied ocean currents and the upper layers of the atmosphere. During the day, they received a radio message from the Norwegian explorer, Thor Heyerdahl, who was heading an international expedition sailing across the Indian Ocean onboard the boat "Tigris."

On 13 February, using the MKF-6M camera, the crew took more pictures of the Soviet Union, concentrating on Siberia and the Soviet Far East. They also spent time on replacing air and water filters with new ones delivered by Progress 1.

On 14 February, they continued their Earth resources work, and also assembled more of the equipment delivered by Progress 1. They installed an electric furnace in the airlock in preparation for a series of technological experiments concerned with the melting of metals. They also installed "a control panel and connecting plug and socket units," and set up photographic and scientific equipment for the experiments.

During the last few days, the cosmonauts had installed replacement generators and other individual instruments in the Soyuz 27 spacecraft. Under their programme of technical experiments, they carried out the testing and adjusting of new optical instruments for space navigation designed for use when the Salyut was under manual control, on either the light or dark side of the Earth.

Metallurgical Experiments

On 15 February, the cosmonauts conducted their first experiment with the electric furnace Splav-01, Splav meaning Alloy. The furnace weighed 23 kg (51 lb) and could be heated to 1000-1100°C (1832-2015°F). On Earth, similar furnaces are very big, their dimensions being determined by very powerful heat insulation. The designers of the Splav furnace solved this problem by designing the furnace to fit into the Salyut's new rear docking unit, where it could be exposed to the vacuum of outer space. (Other Soviet sources indicated that the furnace was mounted in the waste-disposal airlock, or "sluice compartment" as Radio Moscow put it.)

The furnace is controlled by a computer which ensures an accuracy of ±5° of the required temperature. The first experiment, which lasted some 14 hours, was made to study diffusion processes in molten metals in weightlessness. A capsule containing ampoules of copper and indium, aluminium and magnesium, and antimonide and indium was placed in the furnace. After the airlock was depressurized, the furnace was switched on and a computer programme monitored the process of crystallization.

During the experiment, the Salyput/Soyuz 27 complex was allowed to drift, with all its orientation engines switched off, to lessen the influence of any dynamic perturbances on the experiment.

The Splav furnace has three heating areas – one that could maintain temperatures of up to 1100°C (2015°F), a "cold" area that could maintain 600-700°C (1144-1356°F), and a "gradient" area along which there was a linear temperature change between the maximum and minimum furnace heating capabilities. The materials samples were in capsules, and each capsule contained three crystal ampoules that fused when subjected to heating. Specialists explained that this should permit formation of mono-crystals in the "gradient" area, while three-dimensional crystallisation should occur in the hot and cold sections of the furnace.

On 16 February, the two men readied the furnace and associated equipment for a second experiment. They had recently been observing noctiluscent clouds, in an effort to provide geo-physicists with a means of determining the state of the Earth's atmosphere. The silvery clouds are usually found in the polar regions at an altitude of about 80 km (50 miles). The cosmonauts had taken dozens of photos which showed that the clouds divide clearly into three layers, differing in temperature from -130°C to -150°C.

On 17 February, Grechko and Romanenko carried out the second Splav experiment. The research materials were aluminium and tungsten, gallium and molybdenum, and "a semi-conducting material". The aim of the experiment, according to *Novosti*, was to gain an understanding of welding and soldering in space, and to investigate the possibilities of creating new composite materials.

Progress 1 had delivered a device called Svezhest (Freshness) to the Salyut, which the cosmonauts activated for the first time on 17 February. It was designed to ionize the atmosphere in the station, to make the environment more comfortable.

On the evening of the 17th, a conference was held on the

ground to review the week's work which concluded that the productivity of the two cosmonauts in conducting scientific experiments had increased by at least 10%. This increase was in line with a similar phenomena noticed during the Soyuz 18 flight, and was, according to *Tass*, somewhat comparable to an athlete getting a second wind.

On 18 February, Grechko and Romanenko carried out biological experiments with micro-organisms, drosophilas and tissue cultures. The two men checked the progress of the experiments and made sure that the required temperature conditions were being maintained. Two-day old larvae of the drosophilas had been taken onboard Salyut 6 in a nutrient medium "Biotherm-4." at a steady 24°C (75°F). The first flies were observed at the end of December and the reproduction cycle began again, this time under weightless conditions, the aim being to determine the effects of weightlessness on the insects' hereditary systems.

On 20 February, the cosmonauts adjusted the onboard telescope used in the Earth's shadow. For the remainder of each revolution it is kept covered. The telescope has a 1.5 m (1.63 yards) mirror. *Novosti* reported that the station was orbiting at 347 x 332 km (216 x 206 miles) x 91.1 min x 51.6°.

On 21 and 22 February, the crew carried out tests with the telescope, which is fitted with a cooling unit to increase sensitivity. This unit can create temperatures of -269°C. In the afternoon of 22 February, the men rested, and talked with their families over the radio.

On 23 February, they used the Salyut 6 engines to carry out a trajectory correction, following which the parameters of the orbit were 364 x 335 km (226 x 208 miles) x 91.4 min x 51.6°.

On 24 February, the two men studied glaciers on Mt. Everest, as part of their studies in determining the planet's hydro resources. Vladimir Dzhanibekov talked with the crew over the radio, and afterwards he said: "It was great to hear our friends' voices. When you hear them speaking you know at once they are feeling well. Both are in high spirits judging from the questions they ask and the way they put them. They're very energetic. As a matter of fact, they're doing more than the timetable calls for."

On 25 February, Grechko and Romanenko continued their astro-physical observations with the 1.5m telescope. On 26 February, they carried out a further Resonance experiment and continued their studies of the Earth. They also made the first measurements of the UV emissions from heavenly bodies using their UV telescope.

On 27 February, the cosmonauts took pictures of Jupiter and Mars using the UV telescope, and studied remote stars and nebulae. In the afternoon they photographed the *Aurora Borealis* in the Arctic. The telescope was also used to scan the Earth's atmosphere to gather data on the ozone layer.

On 28 February, the crew had another day of rest. They continued the familiar pattern of exercises followed by communication sessions with their families. They also listened to a programme of new Soviet songs, watched films on their VTR equipment and read for a time. They also processed the results of some of their research.

Infra-red Telescope

Novosti gave further details of the telescope that the cosmonauts had been using. It had a 1.5 m mirror and operated in the sub-millimetre range. Known as the BST-1M, it was the largest instrument of its kind to be flown in space, and its detector crystals were cooled by a closed circuit system using liquid helium at a temperature of -269°C.

The cosmonauts made the liquid helium by using "an apparatus with a compressor, two gas refrigerating machines and intermediate heat exchangers." At the decisive stage, the gas was cooled by passing it through an expanding

The international space crew on board Soyuz 27-Salyut 6-Soyuz 28. *Left to right*, Yuri Romanenko, Georgi Grechko, Alexei Gubarev and the Czech cosmonaut Vladimir Remek.

Novosti Press Agency

throttle valve. The two men used the telescope to detect radiation in the infra-red range which is normally cut off from ground observations by the Earth's atmosphere. They also trained the telescope on the Earth to measure properties of the upper atmosphere as an aid to weather forecasting.

They checked the telescope's control system by setting it to follow the movements of Jupiter and Sirius. Their programme of work included observations of the nucleus of the Galaxy, the Orion nebula and interstellar hydrogen clouds. They used a small optical telescope to align the main instrument which enables them to accurately locate any point in the sky or atmosphere.

On 2 March, the many rumours about a forthcoming Soviet-Czech spaceflight were confirmed, when the Soviet Union launched Soyuz 28, carrying a two-man crew – Alexei Gubarev and Czech cosmonaut Vladimir Remek.

Acknowledgements

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[To be continued

NEXT MONTH

On the tenth anniversary of Man's flight into lunar orbit, *Spaceflight* presents a challenging article: "Apollo and Zōnd – Race Around the Moon?" by Nicholas L. Johnson. We continue our well-received review "Missions to Salyut 6" and examine the evidence for "Charon Companion to Pluto." We also take a look at the planet Venus as American space probes start their major examination of the clouds, atmosphere and surface.

Introduction

Though its beginnings are shrouded in mystery, it appears that the Big Bird Reconnaissance Satellite Project began as a back-up to the Air Force's Manned Orbiting Laboratory. This was a programme to test man's military usefulness in space using a Gemini spacecraft attached to a boxcar sized lab. [1]. A contract was given to Lockheed's Missile and Space Division to develop the system. The programme was given the code number 612.

By 1967, the configuration was set well enough to allow the Air Force to place a contract for the Titan IIID booster. This rocket uses only the first two stages and the solid fuel strap-ons of the Titan IIIC and omits the transtage. It is designed to accept an assortment of payloads. The booster uses radio guidance rather than inertial [2]. In 1968, the code number was changed to 467*.

By this time, two space tests of the antenna system had been made. Since the beginning of the United States Orbital reconnaissance effort, two different types of satellites have been used, both of them built by Lockheed around the Agena upper-stage. The search and find type was used for large-area surveillance of Russia and China. They were orbited by Thorad/Agena and remained in orbit for 3 or 4 weeks. The photos taken with moderate resolution optics and infra-red sensors are radioed to a ground station. The other is the close look satellite. Equipped with high resolution optics for examining newly discovered objects, it is launched into a low orbit of some 80 miles (129.03 km) by a Titan IIIB Agena. The onboard engine is used to prevent premature re-entry. After two weeks, it returns a capsule to Earth [3]. Such advanced programmes often had technical problems which upset schedules and increased costs but, despite this, the programme seemed to be coming along fairly well.

By early 1969, the same could not be said of MOL. Caught in a funding squeeze, it had doubled in cost, grown in weight and was four years behind schedule. On 10 June 1969, the new Nixon Administration reluctantly cancelled MOL. With this cancellation, Lockheed's satellite went to the forefront.

One major problem area was the camera system. By early 1970, a tentative launch date of late that year had been set. But as spring became summer, the camera problems proved more difficult than expected. The launch date began to slip into 1971 [4].

For some time, details of the satellite had been leaking out. The satellite was huge – 50 ft. long and 10 ft. in diameter (15.24 x 3.05 m); its payload was about 20,000 lb. (9090 kg). It combined both close look and search and find functions.

The main camera was built by Perkin Elmer and would stay aloft for 2 or 3 months. Officially, it was the low altitude surveillance platform; unofficially 'Big Bird' [5].

Launch

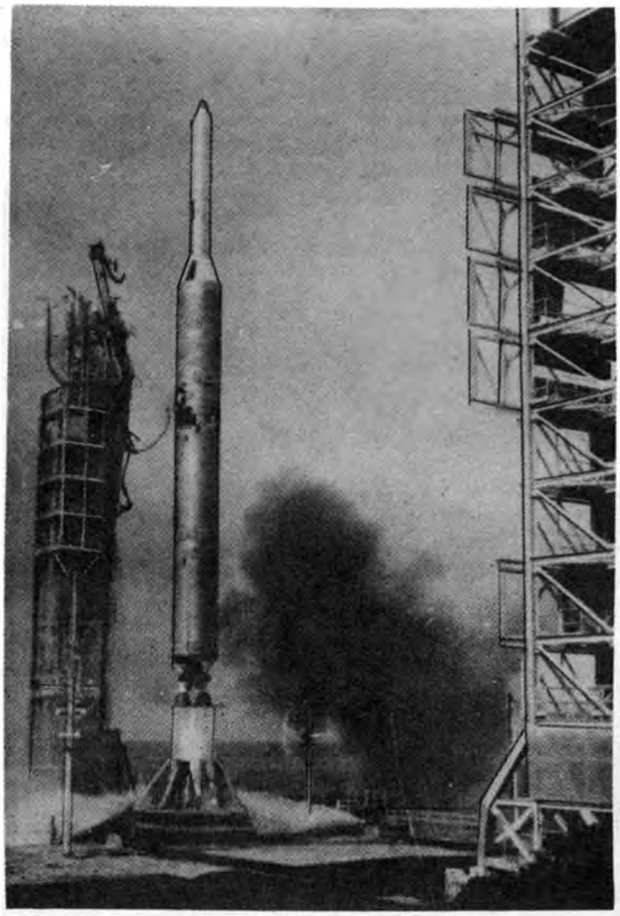
On 15 June 1971, at 11:41 a.m. PDT, Vandenberg Air Force Base reverberated with thunder from Space Launch Center 4 East. The Titan IIID climbed into the California sky and headed out over the Pacific. The Big Bird entered a 114 by 186 mile (184 x 300 km) orbit with a 96.3 degree inclination; the period was 89.1 minutes.

The orbit was Sun synchronous so that each daylight pass over a target would be made with an identical Sun angle. The satellite would pass over every area on Earth twice a day; once in daylight and once in darkness. The ground track would repeat every 3½ days. Big Bird would stay in orbit 52 days.

It was anticipated that the first satellite would undergo tests, particularly of the troubled new camera system, but there were many targets of interest. The previous winter, the Russians were observed to be building two new types of missile silos. By May there were 60 of them. On 27 April, Defense Secretary Melvin Laird disclosed that the Russians had resumed construction on the Moscow anti-ballistic missile complex after a three year halt. And as is now known, the Russians also were preparing a second G-1 booster for launch [6].

Big Bird Described

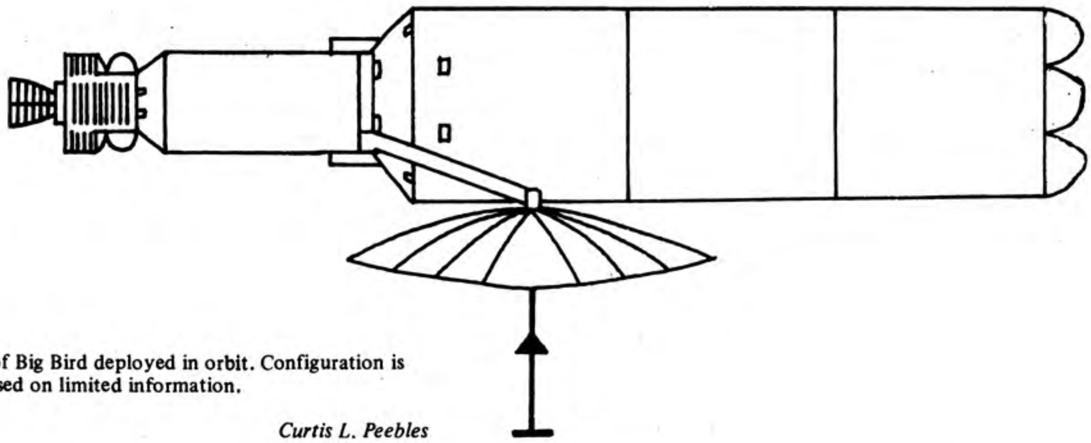
Through the passage of years, enough information has been made public to give some idea of the Big Bird's capacity and configuration. Its heart is the Perkin Elmer optical system. This huge camera takes up most of the nearly 20,000 lb. (9090 kg) payload. Its Cassegrain telescope has



Titan IIIB Agena presently believed to launch both search and find and close look reconnaissance satellites. This launch out of Vandenberg took place on 22 January 1969.

U.S. Air Force

* *Numbers are assigned non-numerically and are changed for security reasons. The similarity between 467 (Big Bird) and 647 (Early Warning Satellite) is probably intentional.*



Artist's conception of Big Bird deployed in orbit. Configuration is provisional and is based on limited information.

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a focal length of 8 ft. (2.44 m) or more. The ground resolution, from 100 miles (161 km), is better than 1 ft. (0.3 m). It can resolve individual people from orbit [7]. A motion compensator moves the film past the shutter at the same speed as the orbital angular motion to prevent blurring.

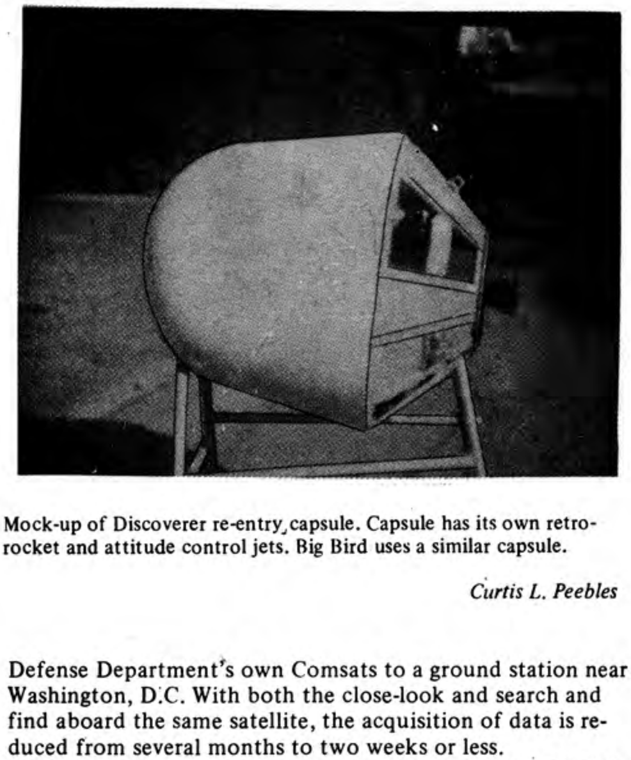
Because of its high resolution, examining old and new photos, of a particular target, can show the slight changes which foretell critical events; a rail extension, new buildings, whose functions can be recognised, or a change in a factory routine [8].

The camera's photos are returned from orbit by "several" recovery capsules. Past close-look satellites returned their capsules after 2 or 3 weeks. Assuming this holds for Big Bird, 5 to 10 capsules would be necessary.† The capsules which have an onboard retro rocket, are recovered in mid-air by specially equipped HC 130's of the 6594th Test Wing off the coast of Hawaii. From there the film is sent, by courier planes, to Andrews Air Force Base outside Washington, D.C., and hence to the National Photographic Interpretation Center of the National Reconnaissance Office, the agency responsible for all over-head reconnaissance, either airborne or satellite.

The payload, also, includes the search and find camera equipment. This camera is equipped with medium resolution optics, manufactured by the Eastman Kodak Company. Similar equipment, flown on the first generation reconnaissance satellites, had two lenses; a lower resolution lens and a much longer, high resolution one. Images from both lenses were simultaneously recorded on the same film. The low resolution photos were examined for any signs of large scale construction and then, going to the appropriate long lens photos, the purpose of such activity could be determined [9].

The Big Bird's equipment is probably more complex including multi-spectral in four or six bands. Multi-spectral photos have proved to be a very effective means of circumventing camouflage and in detecting subtle changes in an area [10]. In the older system, the 70 mm film was processed onboard and then scanned by a laser beam and converted into electronic signals. The Big Bird is believed to use a TV system possibly including live transmission *via* a 20 ft. (6.1 m) unfurled antenna to one of seven ground stations.**

The large antenna allows 16x the transmission rate of the 5 ft. (1.52 m) antenna used on earlier satellites. This would be very valuable if a multi-spectral capacity was included, as it would produce many more photos than a one-band system, all of which must be transmitted during a brief 10-minute pass. The signals are recorded, then re-transmitted *via*



Mock-up of Discoverer re-entry capsule. Capsule has its own retro-rocket and attitude control jets. Big Bird uses a similar capsule.

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Defense Department's own Comsats to a ground station near Washington, D.C. With both the close-look and search and find aboard the same satellite, the acquisition of data is reduced from several months to two weeks or less.

Yet, another area surveillance sensor aboard the Big Bird is an infra-red scanner. It detects the infra-red emissions (heat) of any object. This radiation is at a longer wave length than that recorded by conventional infra-red film. It would be used during the Big Bird's night passes. Such a device could detect the heat leakage from an underground silo being warmed to protect the missile. A decoy target, which may appear normal in visible light, would lack that "lived in" look a real building has. The signals are stored on magnetic tape for radio transmission [11].

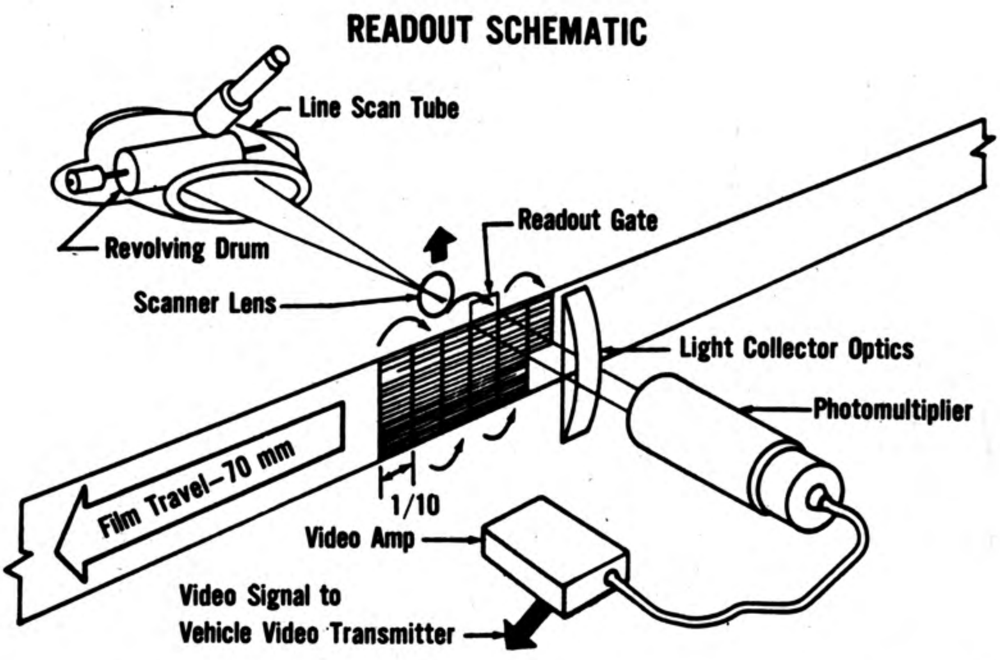
It is believed the payload can be tailored for s specific mission. The spacecraft of approximately 50 x 10 ft. (15.24 x 3.05 m) is built around a modified Agena booster possibly giving it a stepped appearance. The Agena's onboard engine is fired every 7 to 10 days to prevent premature re-

† *The 6 February 1978 'Time' stated that the Big Bird carried six recovery capsules.*

** *New Boston, New Hampshire; Vandenberg Air Force Base, California; Oahu, Hawaii, Kodiak Island, Alaska; Guam; The British Seychelles Island in the Indian Ocean; an unidentified East African Nation as well as six shipboard tracking stations.*

Read-out system system on the Lunar Orbiter. Film is developed on-board and scanned for transmission to Earth.

NASA



NASA SL64-605

entry [12]. It weighs, fuelled, about 29,260 lb. (13.300 kg) and is probably powered by solar cells.

Some Big Birds carry sub-satellite packages. These are P-11, area electronic intelligence packages (Elint). They are octagonal, 1 x 3 ft. (0.3 x 0.9 m) and about 125 lb. (56.82 kg) or more in weight. They are placed in either a 300 or 900 miles high (483 x 1451.61 km) orbit by an on-board rocket engine. They are believed to have "on-line" or near real time data processing. The P-11's primary purpose is to locate and catalogue Russian and Chinese defense radars and their operating characteristics (frequencies, antenna rotation speed, pulse rate and duration and the radar's maximum range). The 900 mile (1451.61 km) satellites are primarily concerned with ABM radars [13].

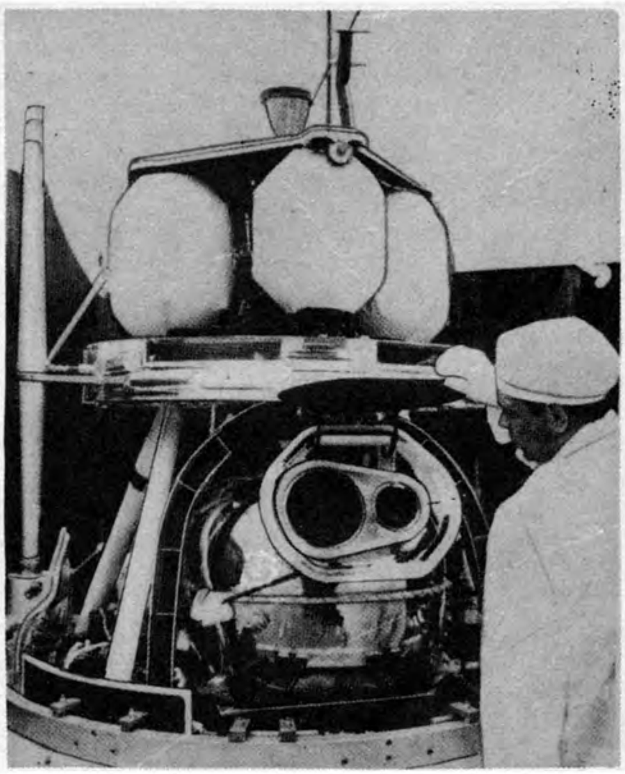
Reconnaissance satellites are supported by Air Force weather satellites. They are launched by a Thor Burner 2 into approximately 500 mile (800 km) circular orbits. Their photos are used to determine if an area will be clear when the reconnaissance satellite makes its pass.

Operations

The second Big Bird was launched on 20 January 1972, remained in orbit for 40 days and carried a P-11 sub-satellite. On 28 May, the SALT I agreement was signed in Moscow. The treaty was to be enforced by "National Technical Means of verification." Furthermore, there would be no interference with said means [14].

The first post-SALT "means of verification" was launched 7 July. Big Bird 3 remained in orbit for 68 days. It carried a P-11 sub-satellite. With this launch, the Big Bird achieved full operational status, only one year after its first flight. The Thorad-Agena search and find satellite was retired, the last launch coming in May.

With the launch of Big Bird 3, a pattern was established. A Titan IIIB Agena spacecraft would be orbited shortly before the Big Bird decayed and would remain for several



Lunar Orbiter camera system. A nearly identical system was used in the first generation reconnaissance satellite. The complete system weighs only 150 lb (68 kg). It carries enough 70 mm Kodak special high definition aerial film to produce 212 dual exposure frames.

Table 1. Big Bird Launches as of 31 December 1977.

Date	Time (UT)	Lifetime (days)	Orbit (km)	Sub-satellites & orbit (km)*
June 15, 1971	.78	52	184-300	None
Jan. 20, 1972	.77	40	157-331	[1] 472-549
July 7, 1972	.74	68	174-251	[1] 497-504
Oct. 10, 1972	.75	90	160-281	None
Mar. 9, 1973	.88	71	156-273	None
July 13, 1973	.85	91	156-269	None
Nov. 10, 1973	.84	123	159-275	[2] 486-508 1419-1458
Apr. 10, 1974	.85	109	153-285	[2] 786-830 503-531
Oct. 29, 1974	.81	141	162-271	[2] 520-535 152-3795
June 8, 1975	.77	150	154-269	[1] (SSU) 1389-1401
Dec. 4, 1975	.86	119	157-234	[1] 236-1558
July 8, 1976	.78	158	159-242	[2] (SESP 74-2) 236-8048 628-632
Dec. 19, 1976	.77	Still in Orbit	247-533	[2] 236-555 253-531
Jun. 27, 1977	.77	178	155-239	None

* *Sub-satellites, other than SSU & SESP 74-2, are Electronic Intelligence (Elint) packages.*

weeks afterwards. It is believed that the Titan IIIB Agena close-look satellite had been modified at this time to function either as close-look or search and find [15].

In the next year, three more Big Birds would be launched, their primary assignments being to re-check the Soviet weapons arsenal. But there were other targets. The third G-1 booster was undergoing check-out through that summer and was still on the pad when Big Bird 4 was launched on 10 October 1972. The activity was monitored until 24 November when the super booster was destroyed after launch. Other missiles, as well, were objects of Big Bird's attention.

Since early 1972, tests of new Russian ICBM's have been underway and by May of 1973, four new missiles had been tested – the SSX-16, SSX-17, SSX-18 and SSX-19. Preparations for the May 1973 tests, which saw the debut of the SSX-19, would have been observed by Big Bird 5; a Titan IIIB Agena would continue after Big Bird's decay.

Big Bird 3 through Big Bird 6 had each shown a lifetime of two or three months but starting with Big Bird 7, they would show a tremendous increase. Big Bird 7, launched on 10 November 1973, remained in orbit 123 days and Big Bird 10 150 days, three times that of the first* [16]. Big Bird 7 also was the first Big Bird to carry two P-11's.

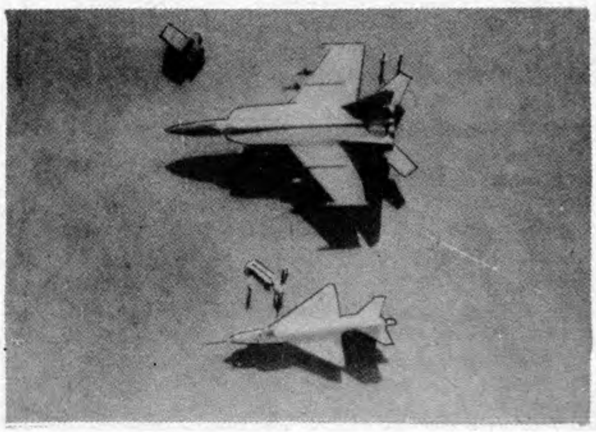
By early 1974, enough information had been gained to determine the SSX-16 was not far along; the SSX-17 was having technical problems and both the SSX-18 and 19 were well advanced [17]. In fact, the SSX-19 had made its first full range flight late that January [18].

Big Bird 8 was launched on 10 April 1974. Then two months later, a Titan IIIB satellite was launched; it decayed shortly before Big Bird 8 re-entered. About two weeks later, another Titan IIIB was launched, staying aloft until late September. Finally, after an unusual three month interval between the Big Birds (the usual delay is one or two months), Big Bird 9 appeared. Shortly before launch, an explanation was made public; it was alleged the Russians were developing a mobile phase array radar system at the Sary Shagan ABM test centre. Submarine construction areas at Severomorsk were being covered by huge canvas shrouds. More importantly, the Russians had attempted to hide the construction of what appeared to be missile silos. That the alleged silos were detected gives some indication of the Big Bird's capability. When the Russians were confronted with the charges, the reports continued, they claimed that they were command and control centres [19].

It was rumoured that the three month delay was to allow modifications of the sensors to counter the Russian camouflage [20].

That same eventful summer, it was reported that the G-1 booster test stand was being modified as well as the reconstruction of the original launch pad destroyed in the 1969

* *The Titan IIIB Agena, also, showed a similar increase but over a longer period of time.*



Simulated Big Bird high resolution photo showing a Soviet Air Force base. Aircraft are a MiG 25 and a MiG 21. Personnel and ground equipment are clearly visible.

Curtis L. Peebles

G-1 explosion [21, 22]. Whatever happened that summer, the regular launch pattern was re-established by mid-'75 and has not been disturbed since – indicating possibly that the Russian camouflage efforts were not effective.

One of Big Bird 9's sub-satellites went into a 75 x 2,343 mile orbit (152 x 3,795 km), the other into a standard 300 mile orbit (483.9 km). Big Bird 11, launched on 4 December 1975, deployed a sub-satellite into a 147 x 966 mile orbit (236 x 1,558 km). Only time would tell if a pattern had started.

By very late 1974 or early 1975, the first deployment of SS-18 was observed [23]. By summer, Big Bird 9 would spot ten SS-17's, ten SS-18's and fifty SS-19's deployed. Also, in 1975, yet another missile test began: that of the SSX-20 mobile missile. It was based on the first two stages of the SSX-16 [24].

In July 1976, the US Arms Control and Disarmament Agency would report the Russians were beginning to equip the 600 IRBM arrayed against NATO and China with multiple, independently targetable re-entry vehicles. The information came from high resolution photos from Big Bird 11. One reason the Air Force spent so much time, effort and money on the camera systems was to enable them to identify the specialised trucks and other equipment necessary for this move [25].

Big Bird 12 was launched on 8 July 1976. By January 1977, the Department of Defense would announce a total of forty SS-17's, more than fifty SS-18's and 140 SS-19's [26].

It is interesting to note that a typical report of twenty-five years earlier read "from 100 to several hundred bombers." This elimination of uncertainty is the reconnaissance satellite's most important contribution.

Birds of a Different Feather

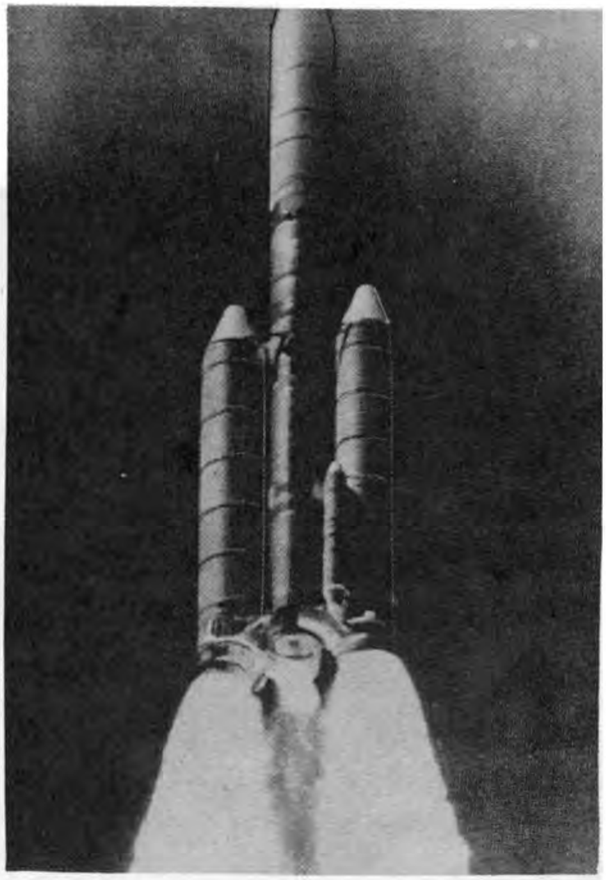
The launch of 19 December 1976 was a curious one. The Titan IIID launched satellite went into a 159 x 330 mile (247 x 533 km) orbit [27]. It was significantly higher than the typical 96 x 167 mile (155 x 270 km) orbit of previous Big Birds. The biggest difference, however, is its lifetime. The satellite 1976-125A was still in orbit at the end of 1977, a lifetime of over one year. The previous record was Big Bird 12's 158 days.

The satellite is the same size as the Big Bird, uses a Titan IIID launch vehicle and has an on-board engine. Its orbit is still low enough for reconnaissance missions, but it would require longer focal length optics for the same resolution as the Big Bird achieves. Complicating things further, a Big Bird (all characteristics point to this) was launched on 27 June 1977 and remained in orbit 178 days [28]. Its mission overlapped that of 1976-125A. The last time a similar overlapping occurred was at the introduction of the Big Bird. With the 1976-125A flight, year-round coverage was achieved, eliminating gaps in coverage that occurred between flights. Details, however, must remain, a matter of speculation.

Conclusions

Reconnaissance satellites are orbital watchmen. As they make their endless rounds, their photos help to preserve the peace by eliminating the fear of the unknown, the possibility of miscalculation based on incomplete information. They make arms control talks possible by eliminating the need for on-site inspection. For the first time, a nation has a complete inventory of a potential enemy's weaponry. Any changes can be detected within 48 hours of the reception of new photos. Each side knows what the other is doing just as each side knows the other side knows.

On 15 March 1967, President Lyndon Johnson gave some insight into the profound changes reconnaissance satellites had made in international relations after only seven years of operation. "I wouldn't want to be quoted on this, but we spent 35-40 billion on the space programme and, if nothing else has come out of it except knowledge we've gained from space photography, it would be worth 10 times what the whole programme has cost because tonight we know how many missiles the enemy has and it turns out that our (previous) guesses were way off. We were doing things we didn't need to do, we were building things we didn't need to build; we were harbouring fears we didn't need to harbour" [29].



Titan IIID booster used to launch Big Bird reconnaissance satellites is capable of putting more than 13.5 tonnes into polar orbit. First launch 15 June 1971.

Official U.S. Air Force photo

The author wishes to thank the Goddard Space Flight Center and the San Diego Aerospace Museum for data used in this article.

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[Continued on page 400

SPACELAB 1 PAYLOAD SPECIALISTS

Two Americans have been named by NASA as part of an international group of five scientists who will serve as payload specialists during the first Spacelab mission scheduled for the latter part of 1980.

Ann F. Whitaker of the Marshall Space Flight Center was one of the six American finalists being considered for the mission but she was not selected. However, she will have a lubrication experiment aboard the Spacelab.

Indicating that she was "a little disappointed" at not being selected, Mrs. Whitaker said she planned to "try again" on a later mission.

One American and one European eventually will be selected to fly aboard the Earth-orbiting space laboratory and operate the science instruments.

The American payload specialists were nominated and selected by the Investigators Working Group (IWG), which is composed of scientists representing all investigators.

Dr. Charles R. "Rick" Chappell, chief of Magnetospheric Physics Branch at Marshall's Space Sciences Lab, is mission scientist for Spacelab 1 and is chairman of the IWG.

U.S. scientists selected were: Dr. Michael L. Lampton, 37, a space physicist at the University of California, Berkeley, and Byron K. Lichtenberg, 30, a vestibular researcher at the Massachusetts Institute of Technology.

The three payload specialists selected by ESA are: Ulf Merbold, 36, German, a scientist at Max Planck Institute, Stuttgart, West Germany; Claude Nicollier, 33, Swiss, a scientist and pilot at the European Space Technology Center (ESTEC), Noordwijk, Netherlands; and Wubbo Ockels, 31, Dutch, a physicist at Groenigen University, Netherlands.

[Claude Nicollier was recently elected a Fellow of the British Interplanetary Society. Ed.]

Payload specialists' responsibilities will be to perform experiments in space aboard the Space Shuttle, which will carry the European-built Spacelab into Earth orbit. They are not pilots.

The three payload specialists who are not chosen to fly in space will act as backup specialists, participating in ground-based mission activities at Johnson Space Center during the flight. This choice will be made some months before the flight.

Lampton and Lichtenberg were selected from a list of six finalists, identified late last year after screening programmes were conducted. The European scientists were selected by the European Space Agency (ESA) from among thousands of applicants in its member states after parallel screening programmes were conducted in Europe.

The first Spacelab will orbit the Earth at an altitude of 250 km (155 miles). At the end of the seven-day mission, the Shuttle will return for a runway-type landing at Kennedy, be serviced and be readied for other missions.

On the Spacelab 1 mission, investigations will be conducted in stratospheric and upper atmospheric physics, materials processing, space plasma physics, life sciences, astronomy, solar physics, Earth observations and space technology.

The Marshall Center is responsible for the payload specialists' training activities as part of its overall management responsibility for the Spacelab mission. ESA's Spacelab Payload and Coordination in Europe (SPICE) organization will manage training activities in Europe.

SPACE PROCESSING CONTRACTS

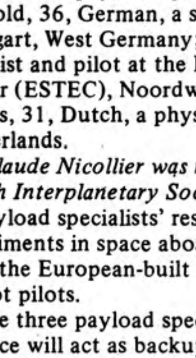
Improved medicines, electrolyte materials for higher-capacity, smaller-size batteries, and larger, more perfect crystals for electronic applications are among a long list of products expected to evolve from materials processing in space research. Seventeen scientists have recently signed contracts with NASA's Marshall Space Flight Center, Huntsville, Alabama, to develop these and other materials experiments that will be among the first to be conducted in the weightless environment offered by the Space Shuttle and Spacelab.

The $12 million programme, covering a five-year initial period, is expected to demonstrate the value of space for materials work by showing significant scientific results to develop specific useful materials and products. The continuing programme is intended to develop space materials science and technology in both research and manufacturing activities leading to privately funded materials processing in space.

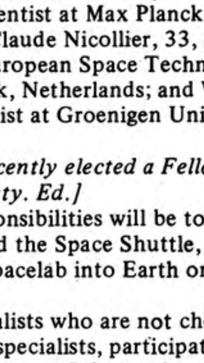
"In the process of selecting these first 17 experiments and working out the conditions of the contracts with the principal investigators," reported John Williams, Marshall Center's experiments manager for the programme, "we have established a management procedure that gives us the flexibility we need for a smooth and effective development of materials processing in space.

"We must plan several years ahead," he continued, "not only to bring other scientists and their experiments into the programme, but to refine and re-fly those experiments that show promise for a better product. Only in this way can we reach our goal of paving the way for private enterprise to commercialize space processing."

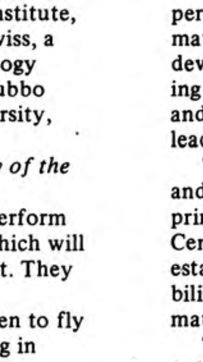
With routine flights into space scheduled to begin next year, scientists will have many opportunities to investigate materials processes that are unsatisfactory or impossible on Earth due to gravity forces. The first experiments will build on results of investigations performed during Apollo, Skylab, Apollo-Soyuz and SPAR Space Processing Applica-



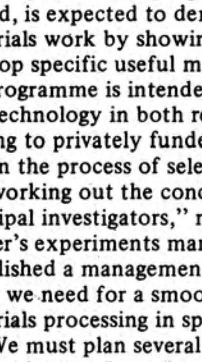
MERBOLD
German



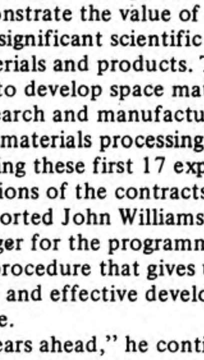
OCKELS
Dutch



NICOLLIER
Swiss



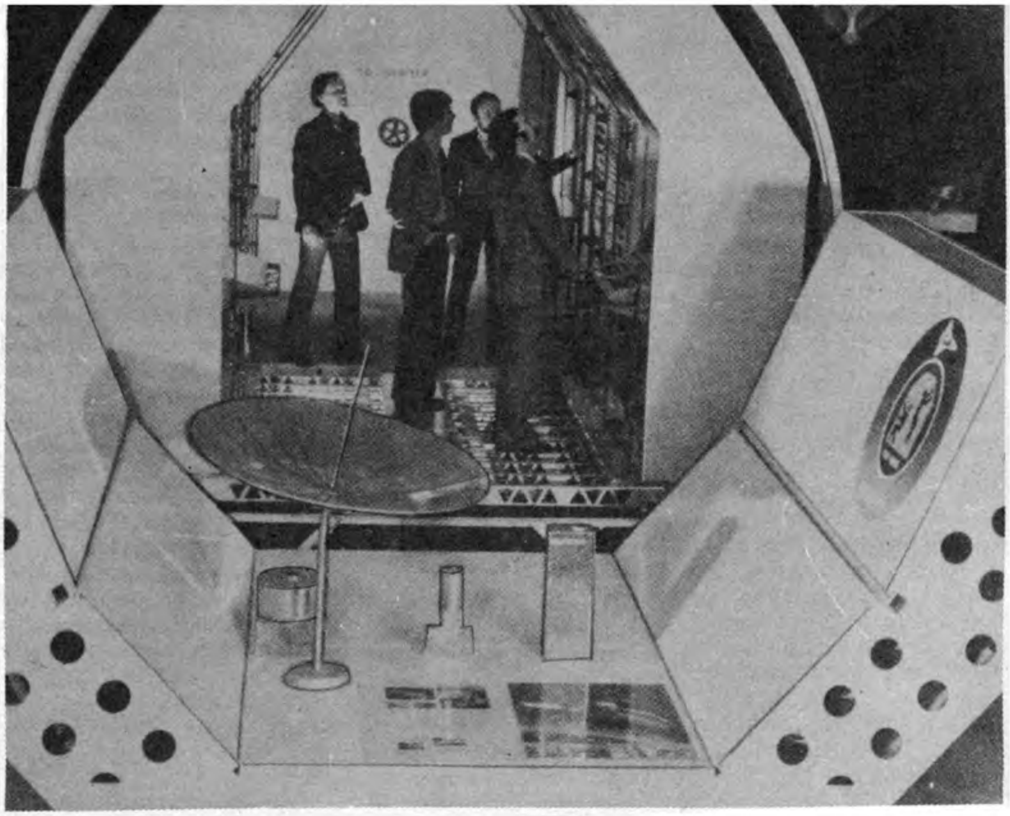
LICHTENBERG
American



LAMPTON
American

The four European candidates for the first Spacelab mission familiarising with the instruments in the full size mockup at the Aviodome (Schiphol airport, Netherlands). *Left to right*, Claude Nicollier (Switzerland), Ulf Merbold (Germany), Franco Malerba (Italy) and Wubbo Ockels (Netherlands). The Italian was later dropped from this mission as the final choice was limited to three Europeans.

European Space Agency ESTEC photo.



tions Rocket programmes. They are expected to develop materials processing and experiment hardware technology for future space commercialization.

Five of the 17 scientists will have an opportunity for a preliminary flight of their experiments in a Materials Experiments Assembly (MEA) package on an early orbital flight test of the Space Shuttle. This flight will not only produce valuable scientific data, but will determine whether further refinement of the experiments and hardware is needed before the first flight on Spacelab or Space Shuttle.

Four of the MEA experiments will be flown again, along with five others, on a Space Shuttle satellite deployment mission. The fifth one will be flown again on the third Spacelab mission, a mission devoted almost entirely to materials processing in space. Four more of the scientists will have experiments on this mission.

The five scientists whose experiments will be flown in the MEA package are:

Dr. John W. Vanderhoff, Lehigh University, Bethlehem, Pa., "Large Particle-Size Monodisperse Latexes."

Dr. J. Bruce Wagner, Jr., Arizona State University, Tempe, "Solid Electrolytes Containing Dispersed Particles."

Dr. Herbert Wiedemeier, Rensselaer Polytechnic Institute, Troy, N.Y., "Vapour Growth of Alloy-Type Semiconductor Crystals."

Ralph A. Happe, Rockwell International, Downey, California, "Containerless Preparation of Advanced Optical Glasses."

Dr. S. H. Gelles, Gelles Associates, Columbus, Ohio, "Liquid Miscibility Gap Materials."

Nine experiments scheduled for the Space Shuttle satellite deployment mission include those flown on the MEA mission by Dr. Vanderhoff, Dr. Wagner, Dr. Wiedemeier and Mr. Happe. The other five are:

Dr. R. Shankar Subramanian, Clarkson College, Potsdam, N.Y., "Phenomena in Containerless Glass Processing."

Dr. Michael C. Weinberg, NASA's Jet Propulsion Laboratory, Pasadena, California, "Fining of Glasses in Space."

Dr. Mirt C. Davidson, Marshall Center's Space Science Laboratory, "Growth of Solid Solution Crystals."

Dr. David J. Larson, Jr., Grumman Aerospace Corporation, Bethpage, N.Y., "Aligned Magnetic Composites."

Dr. Roger K. Crouch, NASA's Langley Research Center, Hampton, Virginia, "Semiconductor Materials Growth in Low-g Environment."

In addition to the MEA experiment by Dr. Vanderhoff, experiments by the following scientists are scheduled on the Spacelab 3 mission:

Wayne F. Schnepple, EG&G, Inc., Goleta, Calif., "HgI_2 Crystal Growth for Nuclear Detectors."

Dr. Rauindra B. Lal, Alabama A&M University, Huntsville, Alabama, "Solution Growth of Crystals in Zero-Gravity."

Dr. Paul J. Schlicta, NASA's Jet Propulsion Laboratory, "Crystal Growth in a Spacecraft Environment."

Dr. Leopold Dintenfass, University of Sydney, Australia, "Aggregation of Human Red Blood Cells."

Scientists whose experiments have been selected but not yet scheduled for flight are:

Dr. Arthur A. Fowle, Arthur D. Little, Inc., Cambridge, Mass., "Investigation of Marangoni Effects in Crystal Processing."

Dr. Milan Bier, University of Arizona, Tempe, "Hormone Purification by Isoelectric Focussing in Space."

Dr. Carel J. van Oss, State University of New York, New York City, "Electrophoresis of Human Pancreatic Cells."

SPACE BEAM BUILDER

A possible tool for building huge space structures, stretching over many square miles in Earth orbit, was unveiled on 13 June at a public demonstration by the Grumman Aerospace Corporation in Bethpage, N.Y.

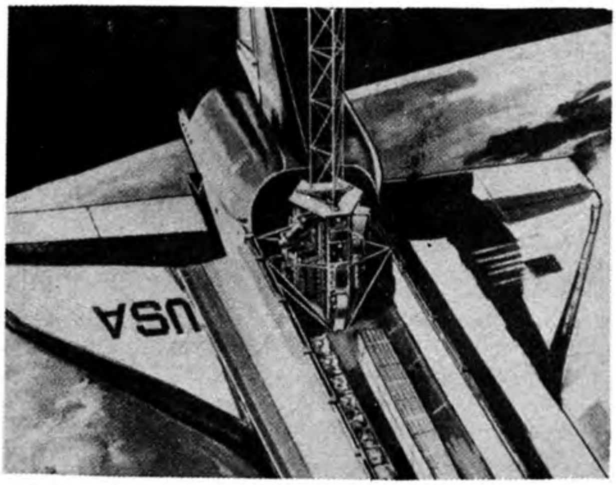
The Automated Beam Builder, designed and built by Grumman for NASA's Marshall Space Flight Center, Huntsville, Alabama, could manufacture construction beams from thin sheets of aluminium transported into space by the Space Shuttle. By rolling out a 40-ft (12.19 metre) long aluminium beam, the Beam Builder demonstrated its intended role in the space programme as one of the first pieces of construction equipment utilizing the Shuttle system.

This test machine will be used by Marshall Center to prove the concept of building beams in the hostile environment of space. At the completion of testing, plans are to modify the machine making it considerably lighter than the test article (16,000 lb instead of 22,000 lb) (7,257 kg instead of 9,979 kg). The lighter version can be taken into orbit by the Space Shuttle.

When the 14-by-8-ft (4.27 by 2.4 metre) machine is mounted in the cargo bay of the Shuttle Orbiter, it will provide the basis for construction of large and varied structures. The machine uses .016-in. (4-mm) thick aluminium, and produces beams weighing 0.85 lb (0.38 kg) per per foot (0.30 metre).

By loading the Beam Builder with a single supply of three rolls of aluminium, it can produce a 3.2-ft (one-metre) beam 1,000 ft (305 metres) long. With easy reloading, such a machine can manufacture beams of unlimited length.

The test machine was recently delivered to the Marshall Center.



BEAM BUILDER forms girders from rolls of aluminium sheet. Mounted in the cargo bay of the Space Shuttle Orbiter, the machine can form beams of unlimited length, at the rate of about 3 ft (0.9 metre) per minute. They can be used in building large structures in orbit for numerous scientific and industrial purposes.

MSFC, National Aeronautics and Space Administration

ANTI-SATELLITE WEAPON

In an endeavour to catch up with the Soviet Union, the U.S. Department of Defense is accelerating development of an anti-satellite weapon. The Vought Corporation interceptor, being developed under a $58.9 million contract, is to be air-launched in initial tests.

SPAR VI EXPERIMENTS

Experiments have been chosen for NASA's sixth Space Processing Applications Rocket (SPAR), tentatively scheduled for launch in late 1978 or early 1979. The space processing experiments were selected at an experiments readiness review held at NASA's Marshall Space Flight Center, Huntsville, Alabama. Criteria for the SPAR VI selections were adequate scientific preparation and maturity of experiment apparatus.

The SPAR project is a continuing series of materials processing in space rocket flights over a five-year period. The rockets each provide about five minutes of near-weightlessness during the coast phase of their sub-orbital trajectories, at which time materials processing experiments are performed.

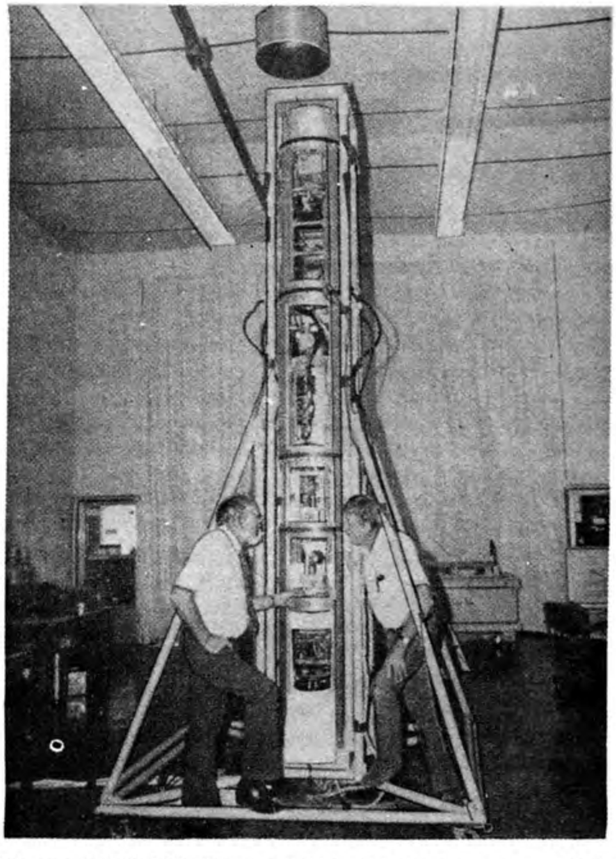
Experiments selected for the SPAR VI flight and the principal investigators who proposed them are:

"Monotectic and Hypermonotectic Solidification," Dr. Claud Potard, Nuclear Research Center of Granoble, France.

"Foam Copper," Prof. Robert B. Pond, Marvalaud, Inc., Westminster, Maryland.

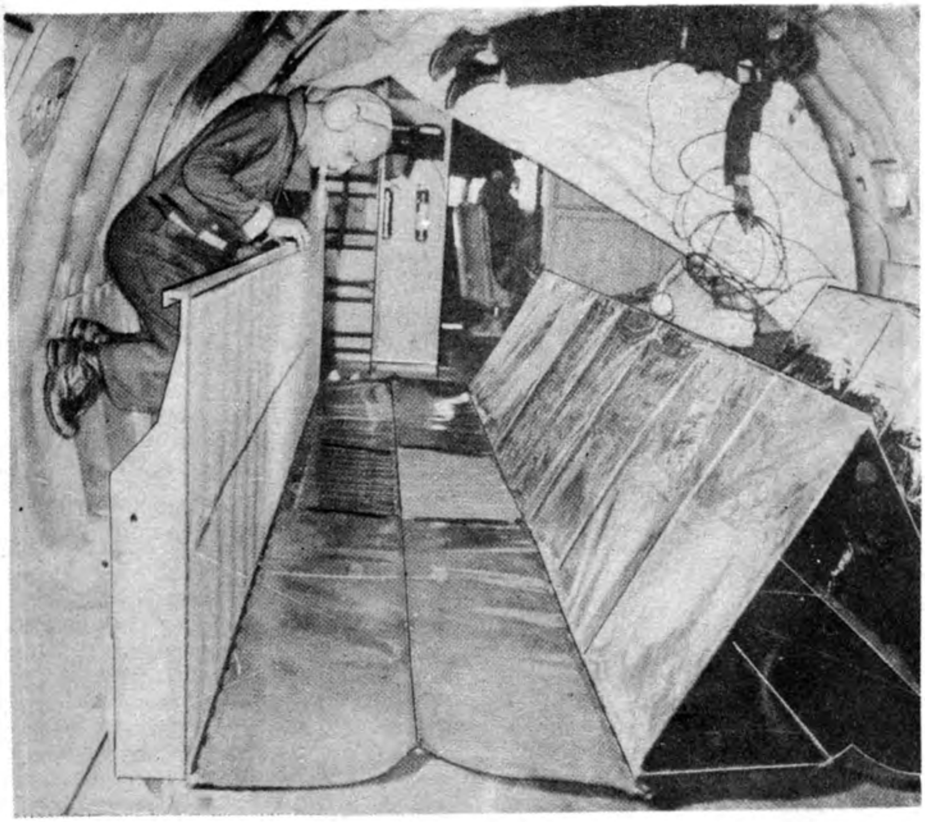
"Directional Solidification of Magnetic Composites," Dr. David J. Larson, Grumman Aerospace, Bethpage, N.Y.

"Containerless Processing Technology," Dr. Taylor G. Wang, NASA's Jet Propulsion Laboratory, Pasadena, California.



SPACE PROCESSOR. This tall cylinder is a mini-laboratory, containing five experiments designed to melt and solidify different materials and record the process for later study. After completing checkout procedures at NASA's Marshall Space Flight Center in Huntsville, Alabama, the lab was fitted to a Black Brandt sounding rocket for a short flight into the fringes of space. During five minutes of near-weightlessness, it will quickly conduct the experiments and electronically record and photograph the entire process. Pictured are engineers Lloyd Engman (left) and Roy Darnell.

MSFC, National Aeronautics and Space Administration



SOLAR ARRAY. Floating inside NASA's KC-135 aircraft during a short period of near weightlessness, engineers test a short section of light-weight solar array being developed for use in orbit. The very thin, flexible solar array section is 13.5 ft (4.1 m) wide and 9 ft (2.74 m) long when extended. Folded, the 9 ft length is compressed to about 0.25 in. (0.63 cm). With solar cells mounted on extremely thin material, the array cannot support itself in normal gravity. By using the 24 seconds of gravity provided by the aircraft, the array can be extended or retracted to prove that it will work properly in space. Marshall Space Flight Center is developing the solar array as a power source for systems in space. The complete array will be more than 100 ft (30.5 m) long.

NASA

POWER IN SPACE: FIRST TEST

The first concrete step toward producing large amounts of power in space will be taken on an early Space Shuttle flight late in 1980 with an experiment flight test of a solar array wing. The experiment will verify the structural and dynamic characteristics of the array, its electrical performance and the readiness of solar array technology for planetary and Earth orbit Shuttle payload applications.

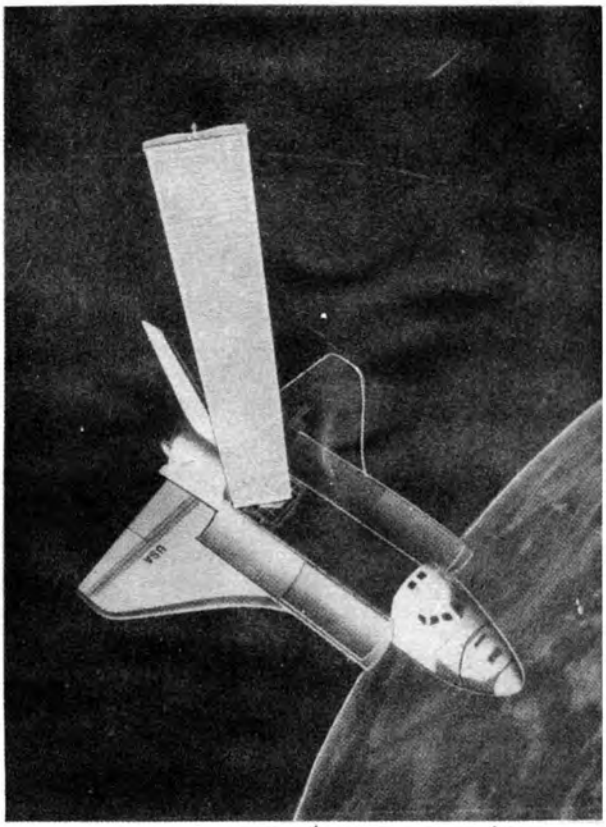
A contract worth $2.7 million has been awarded by NASA's Marshall Space Flight Center to Lockheed Missile and Space Company for development and delivery of the solar array wing by May 1980. It is planned to perform the orbital test the following November.

The solar array wing, measuring 32 metres (105 ft) long and 4.1 metres (13.5 ft) wide, will be folded and stored in the Shuttle's cargo bay during launch. Attached to the cargo bay, it will be extended to its full length and retracted several times during the test.

When fully extended and fully populated with solar cells, the array's 82 panels convert energy from the Sun to produce 12.5 kilowatts of power. For the experiment flight test, only three of the panels will be active.

Demonstration of the experimental solar array wing will pave the way for the use of this technology for power augmentation for Space Shuttle and Spacelab to extend mission duration and later for a solar electric propulsion stage.

NASA's Office of Aeronautics and Space Technology is directing the solar array programme as part of a larger programme which is developing solar electric propulsion for long term missions in the mid-1980's. The solar array technology is relevant to Shuttle payload applications such as a space construction base, satellite power systems, power modules and others.



SHUTTLE POWER WING. A huge solar array wing, 32 metres long by 4.1 metres wide, will be flight-tested on a Space Shuttle late in 1980. The array, with only three of its 82 solar cell modules active, will be extended and retracted from the Shuttle cargo bay several times during the experiment.

ORIGIN OF LIFE

Scientists working for NASA apparently have discovered a way to account for the formation on Earth about 4,000 million years ago of nucleic acids, one of the two most essential components of life. The discovery supplements recent work in which the same investigators discovered a mechanism to explain the formation of the other critical component of life, protein.

Taken together, the findings provide an answer to a vital question that for years has puzzled theorists on the chemical evolution of life on our planet. Basically, the mystery has been:

- How could the building blocks of life – randomly scattered on the shores of primitive oceans – be continuously collected and organized over millions of years in high enough concentrations to produce living organisms?

The scientific team which conducted the investigations at NASA's Ames Research Center, Mountain View, Calif., near San Francisco, consisted of Dr. James Lawless, team leader, of Ames; Dr. Edward Edelson, a National Research Council Associate, and Lewis Manring, a student at the University of Santa Clara.

The newly-found mechanism involves substances which would have been common on the shores of Earth's primitive bodies of water-metal-clays. When low-concentration solutions of DNA-forming nucleotides were mixed with commonplace metal-clays, Dr. Lawless's team found that most clays attracted them. The very long DNA nucleic acid chain in every living cell contains a blueprint of the entire organism.

Furthermore, one type of metal clay, containing zinc, preferentially attracts all six of the building blocks of DNA and RNA (nucleotides). Especially significant is the fact that zinc-clay attracted 97 per cent of nucleotide 5-prime-adenosine monophosphate (AMP). AMP is the most common DNA building block in living systems. Further, AMP with slight modification becomes ATP, the basic energy molecule, present in every life form.

The role of zinc-clay is especially interesting because zinc plays an important role in the enzyme, DNA polymerase, which performs the task of linking DNA building blocks (nucleotides) in living cells to make DNA chains. Enzymes are super-catalysts, which drastically speed up many life processes.

The group did another experiment. The most common DNA nucleotide, 5-prime-adenosine monophosphate (AMP), is composed of three chemical units – a sugar, a purine base and a phosphate group. Three forms of the nucleotide are theoretically possible: a "2-prime" form, a "3-prime" form, and a "5-prime" form, the three differing only in the position of the sugar ring to which the phosphate group is attached. However, only one of these forms is found in living organisms, the "5-prime" form. Dr. Edelson reported that zinc-clay preferentially attracts the "5-prime" form over the "2-prime" and "3-prime" forms.

The work appears even more significant in light of earlier results from Dr. Lawless' group which showed that metal-clays could effectively concentrate amino acides, the building blocks of proteins, and could catalyze their reaction to form polypeptide chains, the basic structual units of proteins. In addition, it was found that certain metal-clays could preferentially attract those amino acids found in the protein of living things today.

Most scientists accept the theory that life began by chemical evolution on the shores of primordial bodies of water. This says that various forms of energy such as lightning, heat and ultraviolet radiation converted the abundant carbon-containing methane, ammonia, and water of the primitive atmosphere into building blocks of life (organic molecules). These molecules, according the theory, then rained into primordial lakes and oceans and joined together into ever-more complex molecules until a molecule or group of molecules appeared which could replicate itself. This was the first living thing.

In recent years, many scientists have performed a large number of chemical evolution experiments. These have produced most of the basic life molecules (including amino acids and nucleotides) in small quantities, by applying electric discharges or other energy release to ammonia, methane, and water vapour. But until now, scientists have been unable to explain how the life-building blocks in the primordial waters were organized.

The group is doing further experiments to see if the zinc-clay preference for the "life-form" of this DNA building block applies to the five others. They are also trying to demonstrate the ability of clays to link up nucleotides into polynucleotides, the next step toward forming a DNA-like molecule.

RARE METEORITE FRAGMENT

Scientists working for NASA and the Smithsonian Institution have confirmed that a meteorite found last winter in the frozen reaches of the Antarctic is one of the rarest types known. The meteorite fragment, which has not yet been named, was found by Dr. William Cassidy of the University of Pittsburgh while on an expedition sponsored by the National Science Foundation.

Called a carbonaceous chondrite because of its high carbon content, the rare meteorite was found with what is believed to be another similar sample and with about 300 other specimens.

The fragment was examined by a team of experts at NASA's Johnson Space Center, comprising Dr. Everett Gibson, JSC geochemist; Dr. Carleton Moore, Director of the Center for Meteorite Studies at Arizona State University, and Dr. Elbert King, University of Houston Geology Department. The initial examination took place with the meteorite inside a lunar-type glove box flushed with dry nitrogen gas. A low-power microscope was used for the initial examination that confirmed the carbonaceous nature of the specimen.

Studies of fragments from this meteorite sample are expected to shed more light on the processes of chemical and physical evolution that may have taken place during the early history of the Solar System, and to enhance our knowledge of the regularity of this evolution in other planetary systems.

Dr. Brian Mason of the Smithsonian Institution, Washington, D.C., and a leading expert on meteorites was sent a 0.4 gram (.014 oz) sample from the fragment. By carefully examining a per-thin slice of this chip, under a high-powered microscope, he was able to observe more details.

The carbonaceous chondrite which was examined is a 19.91 gram (.7 oz) sample about the size and shape of a small egg. The specimen has an overall charcoal grey colour with a slight olive green cast. The interior consists of a fine-grained dark grey matrix with about two to three per cent of crystalline inclusions called chondrules.

The meteorite fragment is a Type 2 carbonaceous chondrite. Fifteen other Type 2 samples have been collected before, but none were in so clean a condition and so well-preserved. The Type 2 carbonaceous chondrites have previously been shown to contain amino acids of a non-terrestrial origin which suggests the chemical formation of the complex organic molecules necessary to life are found in other regions of our Solar System. Carbonaceous chondrites like other meteorites, are 4,500 to 4,600 million years old and preserve a record of how the Solar System formed at that time.

The Johnson Center in Houston is providing special handling and curatorial service for the meteorite collection

because the fragments were found preserved on the cold, sterile Antarctic ice cap in what have been called the "cleanest conditions under which meteorites have been recovered".

The special precautions being taken in the examination and curation of the meteorites arises out of the belief that the fragments have not been significantly contaminated since their arrival on Earth. The samples have been preserved under excellent conditions in the Antarctic. The constant cold and extremely dry air are thought to have kept the samples in a near pristine state, without destroying any of the valuable scientific information that they contain.

It is expected that the Cassidy team will pursue its meteorite search again this winter in the Antarctic.

SIMULATED UNIVERSE

Using the world's most powerful computer as a miniature universe, man is now "seeing" the birth and evolution of stars and galaxies, including his own. He is compressing 200 million years into several hours computer time and reducing the staggering distance light travels in 100,000 years to the length of a television screen to watch galaxies collide and gas clouds beget embryonic stars.

These simulated cosmic events threaten to alter traditional ideas of how galaxies form, what shapes they assume and what happens when they collide. Elliptical galaxies were thought to be oblate – shaped like a frisbee. But computer generated elliptical galaxies by scientists at NASA's Ames Research Center in Mountain View, California, reveal their three dimensional shape to be prolate – oblong, like a cosmic candy bar.

It is beginning to appear to Ames researchers doing much of the pioneering work that computer simulation of cosmic events is an important factor in fully understanding the dynamics of the Universe. The astronomer now has a "laboratory" to test his theories and conduct his experiments.

A scientific team at Ames led by University of Chicago astronomer Dr. Richard Miller and Ames astrophysicist Dr. Bruce Smith are instructing Ames' ILLIAC IV computer – the world's most powerful – to create swirling systems of 100,000 computer points. Each point represents the mass of about one million of our Sun's to give the simulated galaxy a realistic total mass. Each point "feels" the gravitational tugs of its neighbours and "absorbs" energy from exploding supernova.

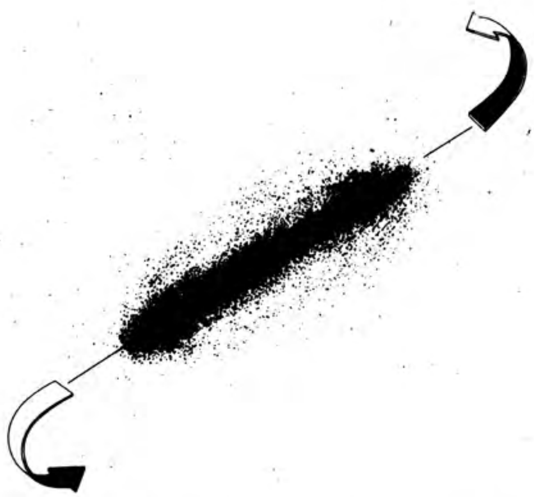
Over the past few years, Miller and Smith have developed a detailed computer program to study the formation and dynamics of galaxies. By coupling this code with the computational power of ILLIAC IV, they have shown computer simulation to be a very useful approach to explaining some basic astrophysical processes.

Miller and Smith routinely follow up to 120,000 "stars" which are free to move about in a "cube" – a three dimensional boundary of space created by the computer corresponding to 100,000 light years edge to edge. They can order ILLIAC IV to rotate the cube so they can watch events from every angle. They can view swirling dust clouds from below or peer down at gigantic galaxial collisions.

Scientists at Ames have filmed several computer simulations. These films reveal events which were not expected according to traditional theories of astrophysics. For example, vast congregations of computer generated stars repeatedly evolve into stable prolate bars. These bars are seen to rotate end over end like a rugger-ball and may be the true shape of elliptical galaxies.

The Ames team suggests that elliptical galaxies seen through the telescope are really the same prolate bars generated by the computer but seen in various projections. Astronomers view snapshots of galaxies projected onto the sky. They have only one view of the galaxy and can only guess its shape, since it would take millions of years to track the galaxy across the sky and view it from a different perspective.

But with a powerful computer, they can "examine" such galaxies from every direction and easily visualize its three dimensional form. Confirmation of the computer's revelations concerning the shape of elliptical galaxies has been reported, based on observed velocities of the galaxies' stars.



PROLATE GALAXY. Artist's representation of 'prolate bar' generated by NASA's ILLIAC IV computer. Vast congregations of computer simulated 'stars' naturally evolve into this galaxy form, rotating end over end as arrows indicate. Prolate bars may be the true shape of so-called 'elliptical' galaxies.

National Aeronautics and Space Administration

COLLIDING GALAXIES. Drs Richard Miller (foreground) and Bruce Smith at Ames Research Center follow two computer-simulated galaxies set on a collision course. Width of the monitor screen represents a distance of 100,000 light years. Use of the computer as an astronomical 'lab' may be a key to fully understanding the dynamics of the Universe.

National Aeronautics and Space Administration

When Miller and Smith set two 50,000 star galaxies on a collision course, there is much greater interaction between the colliding galaxies than was forecast. The galaxies are seen to first contract, their gravitational fields reinforcing each other. But then, they bounce back in a violent expansion that flings hundreds of stars out of the galaxies. The end result is a merger of the two galaxies but with considerably fewer stars.

Curiously, spiral shaped galaxies – such as the one to which Earth belongs – never appear for long without assuming the prolate bar shape. This perplexing situation means that the present state of knowledge concerning the physics of spiral galaxies is inadequate. Other basic physical processes must play a role in the formation of stable spiral galaxies.

Ames researchers are presently following simulated masses of gas as they coalesce and form stars. Some stars are programmed to have a short life, collapsing into brilliant supernova eruptions, spewing their masses out into the primordial galaxy. In this area, too, Miller and Smith are expecting surprises from ILLIAC IV. Perhaps more theories concerning the nature and evolution of the Universe may change as the computer reconstructs events which took place at the beginning of time.

BIS DEVELOPMENT PROGRAMME

BIS 50TH ANNIVERSARY

Although the 50th Anniversary of our Society is still five years away, the Council has been considering ideas for marking this major event in an effective way. We hope to publish a major history of the BIS and, in view of the many unique contributions which members have made in the field of space science and technology – at home and abroad – we approached the Post Office to see if there would be any possibility of a Special Commemorative Issue of Space Stamps in 1983. The Executive Secretary received this reply:

Dear Mr. Carter

Thank you for your letter of 16 May about a special issue of stamps in 1983 to mark the 50th anniversary of the formation of the British Interplanetary Society.

I have added your suggestion to the list of subjects from which the final choice for 1983 special stamps will be made, and it will be carefully considered when we draw up the stamp programme for that year.

I should point out that, since the number of issues which forms a stamp programme is severely limited, we can unfortunately meet only a small part of the great demand for special stamps. I shall write to you again when the final choice for the 1983 stamp programme is made. This will not be until early 1982 but I will be happy to receive any information on your Society that you would care to send which may be useful at the appropriate time.

Incidentally I have just read a most interesting article on the "Daedalus" project by Adrian Berry in *The Daily Telegraph*. It makes one wish that one could still be around a hundred years from now.

K. GAINSFORD
Postal Headquarters,
Counter & Stamp Marketing Division,
St. Martins le Grand, London, EC1A 1HQ.

BIS DEVELOPMENT PROGRAMME

ASTRONAUTICS HISTORY

SPECIAL ISSUES OF JBIS

The Council has decided that special issues of *JBIS* devoted to the history of rocketry and astronautics would be of interest to many members and a valuable addition to the literature of the history of science and technology. Since the B.I.S. has already figured prominently in this field of history the project is all the more a worthwhile undertaking for the Society.

While one need not be a professional historian to submit material, contributions must conform to the high professional standards set for the *JBIS*. Students at both the undergraduate and graduate level are especially encouraged to participate.

The Society has asked Mitchell R. Sharpe, BS, MA, FBIS, to become the Editor. Sharpe is the historian of the Alabama Space and Rocket Center, in Huntsville Alabama, USA, and a well-known historian of astronautics. Besides several books and many articles on the subject, he regularly reads papers at the annual history symposia of the International Astronautical Federation and the triennial International Congress for the History of Science. He is the recipient of the Gold Medal of the Tsiolkovsky National Museum for the History of Cosmonautics, in Kaluga, USSR, and has twice received the Robert H. Goddard Historical Essay Award in the USA.

Suggestions for the new issue as well as proposed articles or abstracts may be sent directly to:

Mitchell R. Sharpe,
Alabama Space and Rocket Center,
7302 Chadwell Road, Huntsville,
Alabama 35802, USA

or to the Society.

All material for publication must be in English. There are no requirements as to length. Other information of interest to potential authors will be found in the notes entitled "Guidance for Authors" on the inside back page of every issue of *JBIS*.

By Curtis Peebles

Introduction

One pioneering feature of the space programme is its use of simulators as a training aid. Although the Link trainer was in use before World War II, for training students in instrument flying, their use did not extend to other fields. As late as the mid-50's, Lt. Michael Collins learned F-86 emergency procedures in a classroom or sitting in the cockpit; clearly not an acceptable procedure for space flight [1].

With the coming of spacecraft, there has been a concurrent increase in the sophistication of the simulators. It was here that the days, weeks and months of work were put in before the mission could be flown.

The Simulators

Several simulators are necessary to train a shuttle crew. First is the Shuttle Mission Simulator which was built by the Singer Company's Link Division. The complex was finished in late August, 1976, and testing and check-out was completed by November. Almost immediately, training for the approach and landing crewmen began.

From the outside, the simulator appears to be a large box on stilts. But inside is a complete Shuttle forward and aft flight deck. The displays are hooked up to two banks of computers. They control the function of the instrumentation, changing the cockpit instrument readings in response to crew action or programmed malfunction.

The windows are backed up by projection screens which transmit images from a camera scan system which moves according to control inputs. During the approach and landing training, it scanned a large scale model of Edwards Air Force Base and surrounding areas. Also, displayed on the screen are computer generated visual effects such as the Earth's horizon, stars, Sun and cloud layers. It also has complete audio effects. One feature different from most previous simulators comes from the aircraft-like nature of the Shuttle. The simulator is mounted on a set of hydraulic jacks which provide a complete 6 degree of freedom motion. Previous simulators were fixed; any motion simulation came through the window projection. With the motion feature, the bobbing and weaving of flights can be simulated. For the launch phase, the entire simulator can be rotated into the vertical.

In addition to the flight displays, the Shuttle Mission Simulator has a full aft flight deck, crew stations and windows. Here the crew is trained in the operations of payload support systems, remote manipulator arm operations using computer generated visual effects and Spacelab support systems [2]. The latter is done by electronically linking the shuttle mission simulator with the spacelab simulator. It consists of a core unit and an experiment segment interior. Its displays are, also, computer controlled. It is used for training crew and ground members in flight systems and as a 1-G trainer for familiarizing crew with the accommodations, habitability, location of equipment, stowage and safety.

The other simulators are used for more limited purposes. One of these is the Orbiter 1-G trainer (ORB 1-G) – a full scale flight deck, mid-deck and mid-body. It will be used for EVA, habitability, ingress, egress, stowage, waste management maintenance and walk-through training. Another is the Remote Manipulator System Task Trainer. It is an aft crew station and payload bay mock-up, equipped with an operating manipulator arm. By using this system, designated members of the crew can gain experience in the deployment and recovery of free-flying packages and satellites, visual and cargo bay camera operations, as well as the software systems. To simulate the weightless satellites, helium filled models are used which duplicate the payload geometry. These two simulators resemble partially finished shuttles.

H.R.H. Prince Charles inside the Shuttle Mission simulator during his visit to the Johnson Space Center on 24 October 1977. The Prince flew two simulated Shuttle landings.

National Aeronautics and Space Administration

At the bottom of a large water tank, at the Johnson Space Center, is the Orbiter Neutral Buoyancy Trainer – a structural representation of the Shuttle crew cabin mid-deck airlock, cargo bay and bay doors. It is used for any EVA training a mission would require. Water tank training was begun during the Gemini programme and has proven to be more effective for EVA training than the brief KC 135 zero-G flights [3].

The flight training device is an aircraft, actually two modified Grumman Gulfstream executive jets. They have been equipped with side force generators, two fin-like devices under the aircraft. Thrust reversers, on the engines, and the left side of the cockpit is identical to that of the Shuttle. With these systems operating, the pilot can reproduce the steep descent of the Shuttle landing. After an extensive flight test programme to eliminate buffeting, it was used extensively during the approach and landing test training [4].

Training Procedures

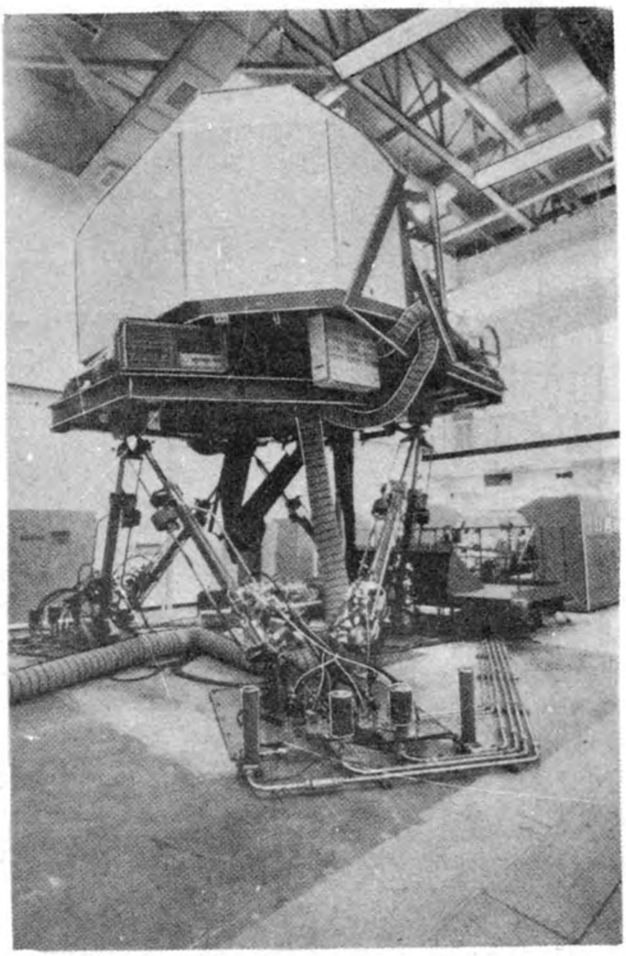
A two year period of study awaits the new shuttle pilot; 1,700 to 1,800 hours of space flight orientation and classroom work dealing with basic space science and Shuttle operations. After successfully completing this, the pilot, for his first flight, will undergo an additional 1,100 to 1,400 hours of training: this to learn the art and science of flying a 185,000 lb. glider. Contrary to what might be expected, the Shuttle handles more like a fighter than the "Brick Airplane" its size would suggest largely because of its electronic fly-by wire system [5].

Left, the computer complex for the Shuttle Mission simulator inside Building 5. Photograph was taken during Prince Charles' October 1977 visit to the Johnson Space Center. Also present are: Dr. Christopher Columbus Kraft, JSC Director, Astronauts C. Gordon Fullerton, Fred Haise, Jr., John Young, Chief of the Astronaut Office, Mr. and Mrs. Roy Fox, Counsel General for Great Britain and other members of the official party.

NASA

Below, head-on-view of Shuttle Mission simulator. It was used extensively during the approach and landing test for the training of the two crews. In the background can be seen the two controlling computers.

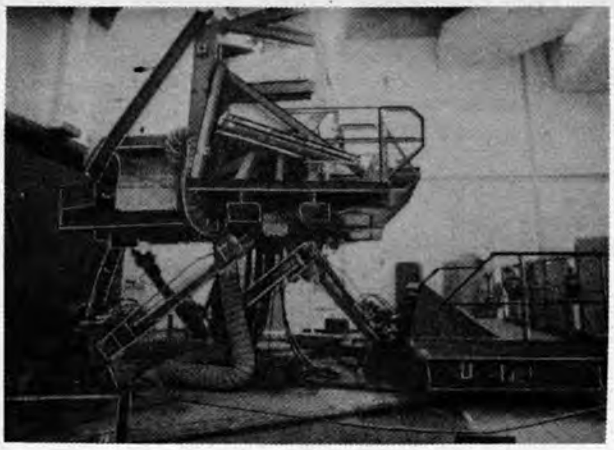
NASA



The Shuttle is flown in three basic modes: full automatic, the control stick steering mode (which might be called semi-automatic) and manual direct. In the first case, the crew simply moniters operations. In the control stick steering mode, the pilot uses the controls to change the Shuttle's heading. Once the manoeuvre is complete, the pilot releases the hand controller and the flight computer maintains that attitude. Holding the controller tends to result in pilot induced oscillations in this mode. In the manual direct, the crew is responsible for all flight functions. This mode can be used at all times except under center of gravity aft conditions.

The most familiar role of the simulator is to reproduce, in safety and comfort, the dangers of space. At lift-off, the Shuttle has three basic abort profiles. If the problem occurs early in the launch sequence, the flight is continued to solid fuel booster jettison. After the boosters are gone, the Orbiter, with the External Tank attached, pitches over to head back to the landing site. Once on a return trajectory, the External Tank is jettisoned and the Shuttle makes a normal approach. If the problem occurs later in the launch phase, the Shuttle will go into a sub-orbital trajectory. For launch out of the Cape, recovery will come at Vandenberg Air Force Base. For launch out of Vandenberg, the recovery would come at Edwards Air Force Base. Because of the Shuttle's 1,100 nautical mile cross range capacity, a number of alternate landing sites are available. Should the emergency occur very late in the launch sequence, the Shuttle will continue into orbit. Then depending on the nature of the problem, the crew would either immediately re-enter or wait to make a normal return to the launch site [6].

Returning from orbit, the crew will use information shown on three cathode ray tubes. These show the projected flight path of the Shuttle based on current conditions. Using it, the crew intercepts the terminal energy management circle which positions the Shuttle for final approach.



Side view of the Shuttle Mission simulator. The hydraulic supports provide 6 degrees of freedom to simulate flight.

National Aeronautics and Space Administration

The cathode ray tubes, also, provide status reports.

The Shuttle will cause a complete change in the operations of the Astronaut Office. During Apollo, only the crews of the upcoming flights were in training. During the 80's, the entire Astronaut Office will be in training for upcoming flights. Once he has flown a mission, a crewman will undergo as little as 200 hours of re-training for subsequent flights to become familiar with the events of the particular mission and retaining an automatic reaction to emergencies.

Another difference is that, for the first time, individuals who are not professional astronauts, will be going into space. These are the payload specialists. The training of such individuals poses many challenges. They will begin training about nine months before launch on a part-time basis attending orientation classes covering such subjects as over-view, emergency and survival and crew station activation/deactivation. It is presently believed a payload specialist, for an Orbiter only flight, will require 180 hours of training. For a Spacelab pallets mission, 234 hours and a complete Spacelab mission would require 239 hours. The classroom and simulator time is broken down as follows:

100 hrs.	Orbiter habitability
5 hrs.	Spacelab habitability
48 hrs.	Integrated crew/ground simulation
32 hrs.	Spacelab phases
21 hrs.	Spacelab systems
10 hrs.	Orbiter phases
23 hrs.	Orbiter systems

Space travel is not easy; worthwhile things rarely are.

Conclusions

When launch date comes for a Shuttle crew, they will have the benefit of perhaps the most complete set of simulators ever available. They will have been tested as well as it is humanly possible to do. This moment is the reward for all those hours of drudgery, yet, without the simulators and the people who run, program and maintain them, this voyage, like all the others, would not be possible.

REFERENCES

1. Collins, Michael, *Carrying the Fire*, Farrar Straus Giroux, 1974.
2. *Aviation Week and Space Technology*, 18 April 1977.
3. *Space Transport System Users Handbook*.
4. *Aviation Week and Space Technology*, 29 November 1976.
5. *Aviation Week and Space Technology*, 9 November 1976.
6. *Aviation Week and Space Technology*, 3 June 1974.

MILESTONES / *Continued from page 362]*

after 25 days. The automatic craft had served to refuel the Salyut 6 propulsion system; air also was replenished from Progress 2 supply. The cargo compartment had been unloaded and subsequently reloaded with waste from the space station. After separation, individual onboard systems of Progress 2 were tested in autonomous flight.

3 *Novosti* reveals that Vladimir Kovalyonok was a backup for Pyotr Klimuk and Vitaly Sevastyanov during two-month mission aboard Salyut 4 in 1975. He was also a back up for Yuri Romanenko and Vladimir Dzhanibekov.

4 *Tass* reports that Progress 2 has burned up in the atmosphere on a predetermined trajectory over the Pacific Ocean.

5 Orbit of Salyut 6 is adjusted in readiness for launch of Progress 3. Cosmonauts continue "technology experiments" including use of the 'Kristall' furnace to obtain semi-conductor mono-crystal of indium antimonide. Another experiment with the furnace sought to obtain "a germanium monocrystal through directed crystallisation."

8 Soviets launch automatic cargo ferry Progress 3 from Tyuratam at 01.31 (Moscow time). "It will deliver equipment, scientific apparatus materials and mail to Salyut 6/Soyuz 29. Orbit parameters are 195 x 249 km x 51.6 deg; period 88.7 min. In the course of the flight, "tests will be made to further perfect the structural elements and the on-board systems and equipment of the cargo ship."

8 NASA launches Pioneer Venus 2 "multi-probe" by Atlas-Centaur 51 at 3.33 a.m. EDT from Cape Canaveral on four-month journey to Venus.(See 'Pioneer Venus 1978,' *Spaceflight*, December 1977, pp. 431-434).

10 Progress 3 docks with Salyut 6/Soyuz 29 at 03.00 hrs (Moscow time). Viktor Blagov, deputy flight director, says: "Whereas Progress 1 and 2 were intended only to replenish space station supplies, Progress 3 is being used to accumulate considerable stocks of food, water and materials to sustain crew activity and functioning of equipment. Foodstuffs 280 kg; water 190 litres; atmosphere regeneration 450 kg. Also revealed that craft brought ampoules containing materials for obtaining alloys and semi-conductors, equipment for space photography of the Earth, materials for biological and medical experiments, etc. Cargo also contains parcels from friends and relatives for the two long-stay cosmonauts and a guitar for Ivanchenkov.

11 Salyut 6 cosmonauts put station complex into gravitational stabilisation mode with attitude systems off to facilitate zero-g experiments to obtain semi-conductor materials using 'Splav' furnace.

SATELLITE DIGEST - 120

Continued from September/October issue, p. 357]

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information sources include the Royal Aircraft Establishment at Farnborough, NASA, Novosti and both the popular and specialist press. For a more detailed summary, see Satellite Digest – 111, January 1978.

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 1012 1978-54A	1978 May 25.61 12.6 days (R) 1978 June 7.2	Sphere + cylinder cone? 5500?	5 long? 2.2 dia?	202	265	62.80	89.15	Plesetsk A-2 USSR/USSR
Molniya-1AR 1978-55A	1978 Jun 2.51 12 years?	Cylinder-cone + 6 panels + 2 antennae 1000?	3.4 long 1.6 dia?	422 412	40840 39941	62.85 62.86	736.26 717.76	Plesetsk A-2 USSR/USSR (1)
Cosmos 1013 1978-56A	1978 Jun 7.91 10 000 years	Spheroid 40?	1.0 long? 0.8 dia?	1480	1557	74.02	116.40	Plesetsk C-1 USSR/USSR
Cosmos 1014 1978-56B	1978 Jun 7.91 10 000 years	Spheroid 40?	1.0 long? 0.8 dia?	1480	1534	74.02	116.15	Plesetsk C-1 USSR/USSR
Cosmos 1015 1978-56C	1978 Jun 7.91 10 000 years	Spheroid 40?	1.0 long? 0.8 dia?	1475	1519	74.02	115.93	Plesetsk C-1 USSR/USSR
Cosmos 1016 1978-56D	1978 Jun 7.91 10 000 years	Spheroid 40?	1.0 long? 0.8 dia?	1473	1501	74.02	115.70	Plesetsk C-1 USSR/USSR
Cosmos 1017 1978-56E	1978 Jun 7.91 9000 years	Spheroid 40?	1.0 long? 0.8 dia?	1460	1495	74.02	115.49	Plesetsk C-1 USSR/USSR
Cosmos 1018 1978-56F	1978 Jun 7.91 9000 years	Spheroid 40?	1.0 long? 0.8 dia?	1444	1491	74.02	115.27	Plesetsk C-1 USSR/USSR
Cosmos 1019 1978-56G	1978 Jun 7.91 8000 years	Spheroid 40?	1.0 long? 0.8 dia?	1425	1491	74.02	115.06	Plesetsk C-1 USSR/USSR
Cosmos 1020 1978-56H	1978 Jun 7.91 8000 years	Spheroid 40?	1.0 long? 0.8 dia?	1410	1487	74.02	114.85	Plesetsk C-1 USSR/USSR
Cosmos 1021 1978-57-A	1978 Jun 10.36 12.85 days (R) 1978 Jun 23.21	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	172 171	316 326	65.03 65.02	89.39 89.46	Plesetsk A-2 USSR/USSR (2)
1978-58A	1978 Jun 10.80 indefinite			35620	35860	0.5	1433.3	ETR Titan 3C DoD/USAF (3)
Cosmos 1022 1978-59A	1978 Jun 12.44 12.76 days (R) 1978 Jun 25.20	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.2 dia?	169 167	348 350	72.86 72.84	89.71 89.69	Plesetsk A-2 USSR/USSR (4)
1978-60A	1978 Jun 14	Cylinder 13 300 fuelled?	20 long? 2 dia?	223 276	509 509	96.96 96.82	91.90 92.42	WTR Titan 3D DoD/USAF (5)
Soyuz 29 1978-61A	1978 Jun 15.85	Sphere + cone-cylinder + antennae 6570?	7.5 long 2.3 dia	193 253 339	248 309 355	51.63 51.64 51.63	88.85 90.07 91.42	Tyuratam-Baikonur A-2 USSR/USSR (6)
GOES 3 1978-62A	1978 Jun 16.46 indefinite	Cylinder + booms 627	2.30 long 1.90 dia	35473 35776	36521 35802	1.78 1.00	1446.9 1436.2	ETR Delta NOAA/NASA (7)
Cosmos 1023 1978-63A	1978 Jun 21.40 120 years	Cylinder + paddles? 750?	2 long? 1 dia?	783	805	74.08	100.76	Plesetsk C-1 USSR/USSR

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Seasat 1 1978-64A	1978 Jun 27.05 200 years	Cylinder + panels 2300	21 long 1.5 dia	776	800	108.02	100.63	WTR Atlas Agena D NASA/NASA (8)
Soyuz 30 1978-65A	1978 Jun 27.65 7.97 days (R) 1978 Jul 5.62	Sphere + cone-cylinder + antennae 6570?	7.5 long 2.3 dia	198 256 334	239 306 344	51.65 51.62 51.63	88.81 90.06 91.25	Tyuratam-Baikonur A-2 USSR/USSR (9)
Cosmos 1024 1978-66A	1978 Jun 28.13 12 years	Cylinder-cone + 6 panels + antennae? 1250?	3.4 long? 1.6 dia?	605 617	40094 39721	62.83 62.76	724.73 717.41	Plesetsk A-2-e USSR/USSR (10)
Cosmos 1025 1978-67A	1978 Jun 28.73			44 638	642 667	82.43 82.49	91.45 97.83	Plesetsk C-1 USSR/USSR (11)
Comstar 1C 1978-68A	1978 Jun 29.93 indefinite	Cylinder 1520 fuelled	2.82 long 2.36 dia	35470	35780	0.08	1428.15	ETR Atlas Centaur COMSAT/NASA (12)
Cosmos 1026 1978-69A	1978 Jul 2.4 4.0 days (R) 1978 Jul 6.4	Sphere + cylinder-cone? 5500?	5 long? 2.2 dia?	207	247	51.78	88.97	Tyuratam-Baikonur A-2 USSR/USSR
Progress 2 1978-70A	1978 Jul 7.47 28 days 1978 Aug 4	Sphere + cone-cylinder + antennae 7020?	8.0 long 2.3 dia	182 248	235 309	51.61 51.63	88.60 90.02	Tyuratam-Baikonur A-2 USSR/USSR (13)

Supplementary notes:

(1) Orbital data are at 1978 Jun 3.1 and 1978 Jun 23.6.
(2) A redundant manoeuvring engine was jettisoned during 1978 Jun 22, designated 1978-57D. Orbital data are at 1978 Jun 10.5 and 1978 Jun 18.4.
(3) 1978-58A may be a missile early warning satellite.
(4) A redundant manoeuvring engine was jettisoned during 1978 Jun 24, designated 1978-59C.
(5) "Big Bird" type reconnaissance satellite. There are four other objects which might also be payloads in similar orbits. Orbital data are at 1978 Jun 15.7 and 1978 Jun 16.5.
(6) Manned spacecraft continuing the occupation of Salyut 6 begun by the Soyuz 26-28 crews earlier in the year, commanded by Col. Vladimir Kovalyonok with civilian Alexander Ivanchenkov flight engineer. Soyuz 29 docked with Salyut 6's forward docking port at 1978 Jun 16.92. Orbital data are at 1978 Jun 16.0, 1978 Jun 16.2 and 1978 Jun 17.1.
(7) Third geostationary meteorological satellite operated by the National Oceanographic and Atmospheric Administration. Its final position is above 135 deg west, replacing GOES 1 (1975-100A) which is to be repositioned at 60 deg east.
(8) Experimental ocean satellite, designed to determine whether microwave instruments are suitable for measuring the surface conditions of the seas. Onboard instruments can measure sea temperature, wind speed, wave heights and detect the presence of ice. The satellite's prime mission is to last one year with the possibility of a two year extension. The basic "bus" of the satellite is the expended Agena stage of the launch vehicle.
(9) Manned spacecraft carrying the second international crew to visit Salyut 6, already occupied by the Soyuz 29 crew. Commanded by Lt. Col. Pyotr Klimuk with flight engineer Major Miroslaw Giermaszewski of the Polish Air Force, Soyuz 30 docked with the aft port of Salyut 6 at 1978 Jun 28.71 and undocked about 1978 Jul 5.5.
(10) Cosmos 1024 may be a missile early warning satellite.
(11) Orbital data are at 1978 Jun 28.7 and 1978 Jun 29.5. The first set of data show the transfer orbit before apogee motor firing to achieve a circular one.
(12) US domestic telephone communications satellite, to be stationed at either 87 or 132 deg west longitude. Its design life is seven years.
(13) Unmanned supply craft carrying consumables to the Soyuz 29 crew aboard Salyut 6. Docking with Salyut 6 occurred at 1978 Jul 9.54 using the recently vacated aft docking port. Orbital data are at 1978 Jul 7.7 and 1978 Jul 7.8.

Amendments and decays:

1967-108A, Cosmos 189 decayed 1978 Jun 8, lifetime 3874 days.
1973-45A, Molniya-2F decayed 1978 Jul 7, lifetime 1822 days.
1976-113A, Cosmos 868 decayed 1978 Jul 8, lifetime 589 days.
1977-25A, Cosmos 901 decayed 1978 Jun 28, lifetime 449 days.
1977-90A, Cosmos 954 decay date should read 1977 Jan 24.
1978-33A, Cosmos 999 decay date was Apr 12.22, lifetime 12.89 days (R).

33RD ANNUAL GENERAL MEETING

A REPORT OF THE DISCUSSIONS

1. PRESIDENT'S ADDRESS

The Chairman welcomed members to the meeting and drew their attention to the Agenda set out in the April issue of *Spaceflight*. This issue also included the Report of the Council for the year 1977. The Report was presented and approved unanimously.

2. BALANCE SHEET AND ACCOUNTS

The attention of the meeting was drawn to the Balance Sheet and Accounts on pp. 154-155 of the April issue of *Spaceflight*. These disclosed another financially successful year which had provided a much-needed surplus to re-establish our investment position. The motion was then put by Mr. G.V.E. Thompson (Vice-President) that all the Accounts submitted be approved. This was seconded by Mr. A.T. Lawton (Fellow) and carried unanimously. The President then drew attention to the financial aspects involved in building our new offices. The Council had looked into the availability of loans to ensure that adequate funds were available to complete the main stages and was able to report the following:-

(a) That Lambeth Borough Council were prepared to provide an interest-free loan, repayable in equal instalments over a five-year period up to a total sum of £5,996.

(b) That the National Westminster Bank were prepared to provide overdraft facilities up to the level of £30,000.

The response to the Council's enquiries had therefore been very favourable, and the fact that people were prepared to lend us money could be taken as a compliment and as an expression of confidence in our future plans. Not only had Lambeth Borough Council offered us the above interest-free loan, but they would also be providing us with a building grant of £8,700.

The Society's Constitution required that no sums of money should be borrowed without the prior assent of an Annual General Meeting. For this reason the arrangements were now put to the Meeting for approval. On the proposal of Mr. M.W. Wholey (Fellow) seconded by Mr. F.R. Smith (Fellow), it was resolved that the Council be authorised to take up these offers.

3. COUNCIL ELECTIONS

The Secretary read out a list of 8 candidates for 5 vacancies on the Council, and drew attention to the procedure adopted at the 1976 Annual General Meeting. He therefore proposed that:-

(a) Ballot papers be prepared immediately.

(b) These would be despatched, together with the subscription notice, in the next (i.e. September-October) issue of *Spaceflight*.

(c) The results would be declared on 31 January 1979.

(d) Scrutineers be appointed to count the returned forms.

Members would note that the combined issue of *Spaceflight* this year was that for September-October, instead of July-August, since it was now clear that this fitted in much more effectively with the holiday arrangements by both our own staff and our printers. These proposals, including the appointment of three Members to act as Scrutineers, were carried unanimously.

4. GENERAL DISCUSSION

The following points emerged during the general discussion:

(a) *Finance*

The surplus shown by the 1977 Accounts had been achieved under extremely difficult conditions. An even heavier work-load had been thrust upon our dedicated staff in 1977 with the preparation of the Daedalus Report which had been a heavy burden to carry on top of an already-overloaded work programme, but which had since been successfully completed.

It was clear that expenditure on rates, insurance, electricity, will all be higher next year. Additionally, expenditure on salaries will need to show a sharp rise, particularly as we extend our activities. Additional furniture and equipment of all sorts will be required, with the financial position exacerbated because we will no longer receive income from our Investments, these having been expended in the construction work.

(b) *Development Fund and the New Headquarters Building*

The interest and support shown in our Development Appeal had been truly phenomenal. The fact that such a substantial sum had been raised by a Society of only 3,000 members was a great achievement. The widespread expressions of support which the Council continued to receive had greatly fortified it in its endeavours to develop the work of the Society in several important directions. The first major step will be the completion of the New Headquarters Building. Regular Reports on the progress of the building work at 27/29 South Lambeth Road, London, S. W. 8, were appearing in *Spaceflight* each month. At the present stage, much of the work was either in the nature of demolition or was not immediately apparent, e.g. a new underground sewerage system was being laid at considerable cost.

The Society looked forward to having its own Conference Room which would be roughly comparable in size with the one normally used in Caxton Hall and having (after allowance for gangways, speaker's area and projection area) a capacity for 50-60 people. This would accommodate many types of Society meetings, though not those which involved a substantial audience. There was some possibility of extending the Conference Room later on, should funds become available, since there was an area of vacant land next to the new offices which, assuming Planning Permission was forthcoming, might be adaptable for this purpose.

(c) *Publications*

The Daedalus Project – Final Report had since appeared and had already proved a great success. Over 2,000 copies had been sold so far. The work reflected great credit on the Society and was a matter for which members could be justly proud. The President, on behalf of the meeting, proposed a vote of thanks to the Editors, their associates and to all who had participated, including our own administrative staff, in such a successful piece of work.

Spaceflight had appeared in 1978 with a new-style format, and other modifications were being investigated which might enhance still further both that magazine and *JBIS*. Publications continued to offer a major area for future development. There was a need to increase advertising revenue and the new rates to be given in a forthcoming issue of *Spaceflight* would allow Members to place small adverts at half the normal cost to encourage greater used of this service.

(d) *Meetings*

Replying to a request for more frequent meetings, the President hoped that when the Conference Room in the new Headquarters building became available attendances would justify more meetings as these could then be held more conveniently than hitherto. Unitl then, administrative priority had to be given to bringing the new building into operation as soon as possible. Meetings that involved a large amount of administrative effort, such as one or two day symposia, would now be scheduled for mid-1979 onwards and in the meantime attention would be given to film shows and popular meetings of, for example, the "space miscellany" type. The Secretary hoped that any members in a position to contribute to this type of meeting would contact him in good time so that he could bring the matter to the attention of the Programme Committee. In response to a request that each meeting should be organized with a back-up programme in case the speaker was unable to come at the last minute, as had recently happened, it was pointed out that alternative facilities would be on hand when we had our own Conference Room and a similar situation could not then arise.

Interest was expressed in meetings to be held in the summer months, although previous experience had shown that fewer members were inclined to attend with the longer evenings of daylight: on the other hand, overseas members tended to visit the U.K. in the summer months and a change had already been foreseen for when the new Conference Room becomes available (*Spaceflight*, October 1977, p. 374).

In response to a question from Mr. D. J. Richer (Associate Fellow) on the policy of joint meetings between the B.I.S. and the R.Ae.S., it was said that all proposals for joint meetings from other bodies were considered with interest and judged on their individual merit. The Society was not aware of any proposals having been made or under consideration.

Mr. I. MacKinlay (Associate Fellow) drew attention to the level of U.K. representation on the Programme Committee of the I.A.F. and to the general lack of support for Space in this country for which the Society should be showing more concern. It was pointed out, in reply, that the Programme Committee of the I.A.F. was nominated by the I.A.F. Bureau itself, who drew upon the best scientists and engineers available, without regard to nationality. The fact that few UK-based representatives appeared to serve tended to reflect the low priority that the U.K. Government gave to Space. This matter had been discussed as a number of earlier B.I.S. meetings, including *several* at which members had been addressed by Members of Parliament.

Mr. D. J. Richer (Associate Fellow) felt that the *Spaceflight* announcement of the forthcoming I.A.F. Congress should have been more specific in announcing a "call for papers." The Secretary replied that anyone contacting the Society's office in response to this announcement would have received all available information concerning the Congress and that programme details would appear in *Spaceflight* when they became available.

[Continued on page 400

CORRESPONDENCE

The Soviet Space Shuttle

Sir, Over the past few years, rumours have abounded that the Soviet Union is developing its own Space Shuttle under the code-name Kosmolet (Kosmicheskiy Samolet – "Space Plane"), but official evidence for such a programme has been close to nil. However, recently Radio Moscow gave details which confirmed that such a programme was being undertaken.

In answer to a listener's question about a possible Soviet space shuttle, the North American service of Radio Moscow said that the Soviet vehicle was different in design to the American vehicle. "The craft will resemble an aeroplane, with delta wings and a cigar-like fuselage. Its rear part will carry three powerful rocket engines. The overall length of the vehicle will be about 200 ft, and its diameter with fuel containers around 26 ft....... The Soviet design calls for a specially designed launcher powered by rocket engines." (BBC Summary of World Broadcasts, SU/5850/C/4, 28 June 1978, quoting a report made on 11 June).

For comparison, the NASA Space Shuttle will be about 184 ft in overall length (Orbiter along 122 ft), with a wing span of 78 ft (expendable fuel tank diameter 27.5 ft).

These figures suggest to the writer that the Soviet vehicle will probably have parallel staging, as does the American vehicle, and will certainly be comparable in size. If this is so, one wonders how the two twin Cosmos flights (881-882 and 997-998), often linked in the West with Kosmolet development, actually relate to the Soviet Shuttle proper.

When the Soviet Shuttle appears, it will be interesting to see the design of the engine system (1 orbiter engine, plus 2 liquid fuel strap-on boosters?) compared with the known Soviet rocket engines. The above figures suggest that the Proton vehicle cannot be directly used to launch the vehicle, other than *possibly* with the core stage acting for the strap-on boosters. The main engine will certainly be of a new type, and will possibly be an up-rated engine of the type designed to launch the giant Type-G launch vehicle, which presumably has now been scrapped in favour of the Shuttle programme (no Type-G launches have come since November 1972, the last launch failure).

Future developments are awaited with interest.

PHILLIP S. CLARK,
Bradford, West Yorks.

'Die Rakete' and the Golden Zepter

Sir, First, I must say that I like very much the new design for the front cover of *Spaceflight*, particularly the very attractive lettering of the title and the presence of the B.I.S. symbol on every cover.

I remember meeting Fred Ordway in Cocoa Beach on the Apollo 16 trip, and I was very interested to read his letter in the February issue. But it seems that while clearing up a mystery he has caused a little more confusion!

First, in the passage he quotes from the introduction to the book of collected reprints of *Die Rakete* it says that the issue dated January-June contains 28 pages, but in his last sentence he credits it with only 24.

Secondly, in referring to the article and letter by Frank H. Winter which he mentions I found two more puzzling matters.

First, the picture caption on page 243 of the July-August 1977 issue refers to "*Die Rakete*, January-June 1927, p.84", which is rather odd if this publication has only 24 (or 28) pages. And in the second paragraph of his letter on page 336 of the September issue there is a reference to p.82 of the same publication. Since this latter reference also mentions that it is from the "article relating to the foundation of the Society", and since it seems more likely that the photograph of the Society's birthplace would also accompany that article (the photograph could hardly appear in material originally published *before* the foundation of the Society), and since the issue dated 15th July 1927 begins with page 81, it seems likely that both these references should be to that issue. One would expect the article about the formation of the Society to be near the beginning of its first official publication, after all!

RAY WARD
Sheffield, England

Frederick Ordway replies:

In response to reader Ray Ward's enquiry, the January-June 1927 compilatory issue of 'Die Rakete' was 28 pages long. Unfortunately, a typographical error crept into the last line of my comments [1] on Frank Winter's article [2] and subsequent letter [3]. The correct figure–28 pages–is given three paragraphs earlier.

Mr. Ward's second question was: Why does the picture of the Golden Zepter appear on p.84 of the January-June 1927 compilatory issue as reported in [2] when the VfR was not born until 5 July 1927? Well, the picture does appear on p.84, but that page is in the 15 July 1927 issue of the journal–the first "regular" VfR-issued 'Die Rakete'. Of course, as I pointed out in [1], the lineal first issue of the publication that became 'Die Rakete' was entitled 'Deutsche Jugend-Zeitung' and it was dated January 1927. It was not until 15 April 1927 that a journal bearing the name 'Die Rakete' appeared [4], nearly three months **before** the birth of the VfR.

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1. Ordway, Frederick I., "On the VfR and 'Die Rakete' ", *Spaceflight* 20, No.2, pp. 78-79, 1978.
2. Winter, Frank H., "Birth of the VfR: The Start of Modern Astronautics", *Spaceflight* 19, Nos. 7 & 8, pp. 243-256, 1977.
3. Winter, Frank H., "The VfR and 'Die Rakete' ", *Spaceflight* 19, No. 9, p. 336, 1977.
4. Ordway, Frederick I., "On the VfR and 'Die Rakete' ", *Spaceflight* 20, No.2, pp. 78-79, 1978.

Origin of Life

Sir, In reference to P. M. Molton's papers (JBIS, Vol. 31, No. 4, April 1978), it is important to point to the implications in origin-of-life research, as the author has, in Section 5, p. 152; to the layman, this work seems esoteric, at most. However, I find the argument that altruism is a characteristic or motive for a species which has mastered FTL Travel hard to accept. Our civilization has an ever increasing interest in SETI activities; if one accepts the ideas expressed in paragraph 6, Section 6, p. 160, our present efforts would appear to be suicidal.

The chances of contacting an advanced society are much greater than those of finding a primitive one; I doubt very much if we would ever revert to an agrarian society, because of the discovery. Human society is accepting the idea that we are probably one of many civilizations, and man's "pathological" curiosity is that which wards off our fear of isolation. Indeed, loneliness will probably be the major factor in the depression and regression of our civilization.

Therefore, current and future SETI activity may be imperative to our survival.

K. J. O'BRIEN
97 Waterford Bridge Road, St. John's,
Newfoundland, Canada, A1E 1C7.

Naming Planetary Features

Sir, I read with interest Robert Bison's letter regarding his concern about the naming of features on the planets of our Solar System [1], and I must admit to sharing his views – but with reservations.

It must be remembered that there are four "earthlike" planets and at least thirty-four natural planetary satellites in our Solar System (excluding the Earth and the Moon), all of which are no doubt pitted in craters and covered by mountains and "seas". Exactly how many different features for which names are required exist on these bodies, I have no intention of guessing but anyone can see what an enormous task it would be to choose a different, awe-inspiring name for each one. I rather fear that we are fated to make do with a computer-like nomenclature for the smaller worlds, similar to that which exists in the naming of stars in astronomy where the members of a constellation are given letters of the Greek alphabet in order of descending magnitude, e.g. *Alpha, Lyrae, Beta Lyrae, Gamma Lyrae* and so on *ad nauseum.* In this way only the most striking features of a planet or satellite would be named, and anything else within reasonable proximity would be given the same name coupled with a Greek letter. (This has already been done to a small extent on the Moon).

The only other alternative I can see is Mr. Gibson's suggestion that a "New name for a new world should be completely new" [1]. Certainly, the number of words that can be created from the English alphabet is infinite, but keeping them pronouncable and appropriate is a different matter entirely.

In conclusion, I feel that the donation of original and suitable names to features throughout the Solar System is an almost impossible task, although I feel that the 15th General Assembly of the IAU ought to have done better than "pinch" 130 names of lunar features when they christened 189 large Martian craters in 1973.

When the Solar System becomes one vast metropolis of human activity – as it will surely do in the future – then it may well be confusing to talk about visiting Copernicus, Tycho or Schiaparelli when a trip to the "wrong one" could result in a wasted journey of some sixty million miles or so!

Incidentally, Mr. Gibson can rest in peace about the crater Birmingham that he spotted on the northern edge of the *Mare Frigoris.* This 98 kilometre wide crater remnant was not named after the city we know and love from watching "Crossroads," but after a respected Irish selenographer called John Birmingham (1829-1884 [2].

MICK WEST
West Bridgford, Nottingham

REFERENCES

1. Correspondence, *Spaceflight,* August 1978.
2. *Moon, Mars and Venus,* Paul Hamlyn, London, 1976, p. 82

"Clarke Orbit"

Sir, With regard to Henry Spencer's letter (*Spaceflight* August 1978), may I point out that the term 'Clarke Orbit' is perhaps already in more general usage than Mr. Spencer realises. For instance, both Patrick Moore and I have used it regularly in our books; see *Space* by Patrick Moore (Lutterworth Press, first published in 1968) and my *Rockets and Satellites* (World (World's Work, 1976) for just two examples. In the former, Dr. Moore himself suggested that the term 'Clarke Orbit' should be used.

I feel sure that very few members will disagree with the adoption of this usage.

DAVID A. HARDY
Hall Green, Birmingham

33rd Annual General Meeting

Continued from page 398]

(e) *Membership*

A decline in the number of members in 1977, even though marginal, had been noted by the Council with great concern. For this reason they had already embarked upon an extensive "Membership Recruitment" campaign which was beginning to show considerable success with the new Membership totals already making good the earlier losses. The capaign would be extended still further during the coming months and the hope was expressed that *every member of the Society would identify himself very closely with this work and do his utmost to enhance the prestige and increase the Membership of the Society.* This was made all the more vital by the fact that we would shortly be moving into our new premises and would be seeking a much more extensive Membership base on which to build for the future.

(f) *Press Publicity*

In response to a question on whether the Society had a Press Officer, the information was given that enquiries stemming from the Press, Radio and TV were dealt with by the Secretary and Mr. K. W. Gatland, with other arrangements made in special cases where this was clearly desirable, e.g. enquiries regarding Daedalus were referred to Dr. Martin and Alan Bond.

(g) *Vote of Thanks*

Mr. C. M. Hempshell (Senior Member) proposed a Vote of Thanks to the Society's Staff which the meeting approved with a resounding round of applause.

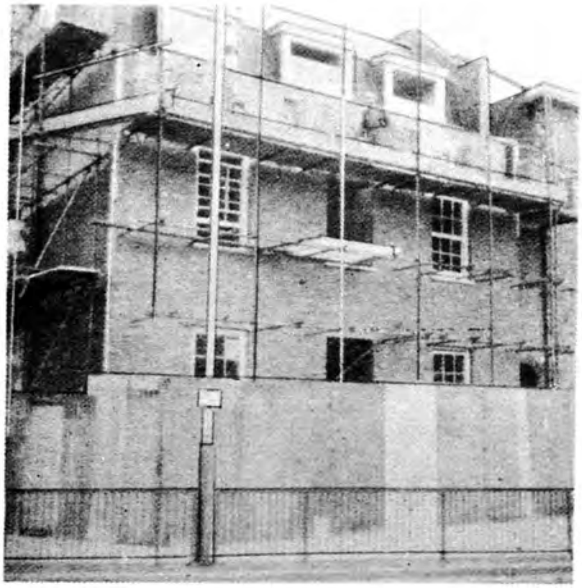
THE GUARDIANS

Continued from page 385]

12. Reginald Turnill, *Observers' Book of Unmanned Spacecraft,* Frederick Warne & Co. Ltd. 1974.
13. *Secret Sentries in Space,* pp. 188-190.
14. *Times Pickeyune,* 29 May 1972.
15. *Aviation Week & Space Technology,* 12 February 1973.
16. *Aviation Week & Space Technology,* 7 July 1975.
17. *Aviation Week & Space Technology,* 6 May 1974.
18. *Aviation Week & Space Technology,* 4 February 1974.
19. *Aviation Week & Space Technology,* 21 October 1974.
20. *Aviation Week & Space Technology,* 11 November 1974.
21. *Aviation Week & Space Technology,* 2 September 1974.
22. *Aviation Week & Space Technology,* 9 December 1974.
23. *New York Times,* 14 January 1975.
24. *The Soviet War Machine,* Salamander Books, 1976.
25. *Spaceflight,* October 1976.
26. *Air Force Magazine,* March 1977.
27. *Spaceflight,* June 1977.
28. *Spaceflight,* December 1977.
29. Chalmers M. Roberts, *The Nuclear Years,* Prager Publishers 1970.

BIS DEVELOPMENT PROGRAMME

PROGRESS REPORT – 6



Building work associated with the re-development of our offices attracts considerable attention on the part of passengers on the high-level Southern Region train service which runs past Vauxhall Station nearby. From that vantage point, passengers enjoy a bird's eye view of the work going on and are curious to know what the eventual result will be, the former garish *Dalton's Weekly* building having been a familiar eyesore for years.

The work now visible from the exterior is the building up of the new brick front to No. 27 and the construction of the "link" to join it to No. 29. This is having the effect of unifying the two buildings and blending them together rather well.

On the inside, holes having been made in the sides of both existing buildings to support the new floors which will be constructed as the link goes up; new concrete floors have been laid in No. 27 and even a little plastering done, though it never fails but amaze to see the sheer weight and volume of the work to be done. Access to No. 27 is rather more difficult than formerly, for the previous stairway has been taken down in order to introduce new storage areas, so access to the higher floors is by near-vertical ladder, a stimulating form of access for the agile but hazardous to the rest, and with descent akin to flinging oneself over a ravine.

Behind the protective boarding, the concrete frontage has been laid out, ready to receive the front railings which will further blend together the two premises. The railings, incidentally, had to be specially made in accordance with the requirements of the Historic Buildings Commission. Fortunately, one or two of the former cast-iron railings escaped the attention of decades of vandals so reproduction will be relatively easy to match.

The stairway inside No. 29, already badly damaged by fire, has also been removed and a new stairway, again moulded to reproduce the original as faithfully as possible, is being installed. Since the sections of this are still incomplete, again, access and egress involves taking one's life into one's hands.

Present indications are that the work is still approaching the half-way mark, though the general knocking about is due to continue for some time yet, with several openings still to be filled in in some places and cut through the walls in others. However, the general transition from the early days is already most marked, with photographs taken by the Society during the various stages of the work showing the usual story of transition from chaos to even more chaos, to utter chaos, and then, eventually, to some glimmering of light.

In the process of laying the foundations for the link the remains of four 19th century clay pipes were unearthed. These are to be the subject of a separate letter to 'Spaceflight' from Mr. A. T. Lawton later on.

On the financial side, the total amount standing to the Society's Development Appeal Account was pressed into service to meet two of the building instalments. It was a shame to see funds which have taken so long to accumulate expended so quickly, but, nevertheless, they went in a good cause.

1979 SUBSCRIPTIONS

No change has taken place in the basic Subscription Rates for 1979 which are detailed below. Renewal forms appear in this issue of 'Spaceflight'.

	Sterling	*US Dollars*
Members (under 21)	£9.50	$20.00
Members (21 and over)	£10.50	$22.00
Senior Members	£11.00	$23.00
Associate Fellows	£11.50	$24.00
Fellows	£12.00	$25.00

The above fees include the receipt of *one* of the Society's publications. A further £11.50 ($24.00) should be added where members wish to receive *both* publications.

Members who remit by Bankers Orders are urged to ensure that the amounts authorised are the current rates.

Remittances from Europe must indicate a UK address at which payment will be made

Payments may be made by GIRO – either in the UK or abroad. Our account number is 53 330 4008.

International Money Orders from USA or Canada can only be cashed if expressed to be payable in sterling. (Internal money orders from those countries cannot be cashed abroad).

Fellows, Associate Fellows, Senior Members and Members who are 65 years and over on 1 January 1979 may claim a reduction of £1.00 ($2.00) from their annual subscriptions.

Remittances may be sent now to:-

The British Interplanetary Society,
12 Bessborough Gardens, London, SW1V 2JJ, England.

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: Tel: 01-821 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor 12, Bessborough Gardens, London, SW1V 2JJ.

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Visit

A tour of the Astronomy and Space Galleries of the Science Museum, Exhibition Road, London, S.W.7., accompanied by Dr. John Becklake, will take place on **2 November 1978**, commencing at 6.30 p.m.

Admission (restricted to members only) will be by ticket available from the Executive Secretary on request enclosing a **reply-paid envelope.**

Film Show

To be held in the Botany Lecture Theatre, University College London, Gower Street, London, W.C.1. on **15 November 1978**, 6.30-8.30 p.m.

The programme will be as follows:

(a) Remote Possibilities
(b) The Weather Watchers
(c) If One Today, Two Tomorrow
(d) Mercury, Exploration of a Planet (repeat)

Admission tickets are not required. Members may introduce guests.

Lecture

Title **A REVIEW OF BRITISH SPACE PROSPECTS**
by P. J. Conchie.

To be held in the Lecture Theatre, Royal Society of Arts, John Adam Street, London, W.C.2. on **1 December 1978**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

General Meeting

Title **SPACE MISCELLANY – 1**

To be held in the Botany Lecture Theatre, Gower Street, London, W.C.1. on **12 December 1978**, at 6.30-8.30 p.m.

Another opportunity for members to talk about models, or souvenirs and other items connected with space projects.

(1) M. Irvine will talk on "Space Models"

(2) L. J. Carter will talk on "Ideas for Space Collections."

Members interested in presenting short contributions to later meetings of this nature are invited to send details to the Executive Secretary.

Admission tickets are not required. Members may introduce guests.

Visit

A second opportunity to tour the Astronomy and Space Galleries of the Science Museum, Exhibition Road, London, S.W.7., for those unable to participate first time around, will be given on **17 January 1979** at 6.30 p.m.

Admission (restricted to members only) will be by ticket only, available from the Executive Secretary enclosing a **reply-paid envelope.**

Short Papers Evening

Title **EXOTIC SEMI-CONDUCTOR MATERIALS**
by A. T. Lawton

Title **INTERSTELLAR COLONISATION**
by Dr. L. J. Cox.

To be held in the Kent Room of Caxton Hall, Caxton Street, London, S.W.1. on **1 February 1979**, 6.30-9.30 p.m.

Admission tickets are not required. Members may introduce guests.

3rd BIS CONFERENCE ON INTERSTELLAR STUDIES

The Society has previously held two conferences, on the topics of Interstellar Travel and Communication, in 1976 and 1977. In organising the 3rd Conference of the Series the title has been changed to indicate the wide range of topics which have been discussed, and a longer time has been allowed between conferences to aid the preparation of material.

The Conference will be held in the Chemistry Lecture Theatre, University College, London, W.C.1., on Wednesday and Thursday, **19-20 September 1979**.

Papers have already been promised on propulsion systems, exobiology, human expansion into the Galaxy and the evolution of intelligence.

Applications for registration forms, and notification of the intention to submit a paper for the Conference, should be made to: The Executive Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ, England.

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SPACEFLIGHT

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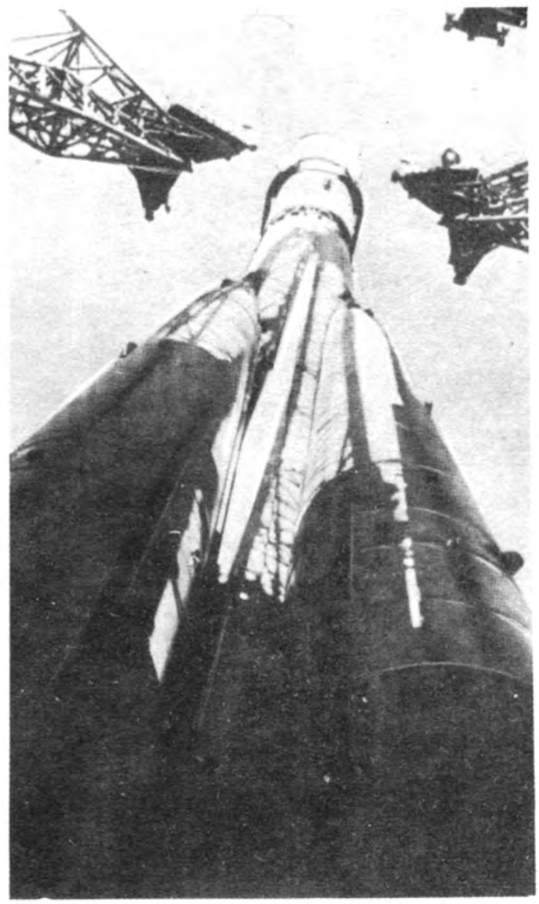

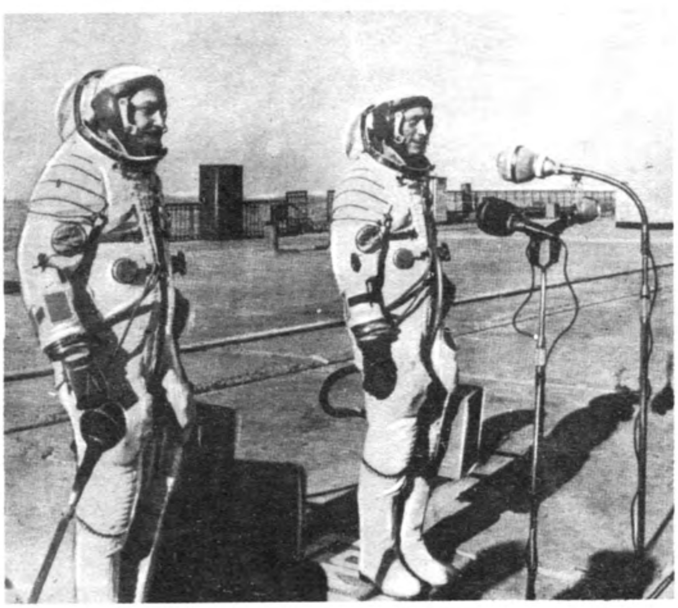

VOLUME 20 No. 12 DECEMBER 1978

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SPACEFLIGHT

BIS DEVELOPMENT PROGRAMME

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BIS DEVELOPMENT PROGRAMME

SCIENCE AND EDUCATION

SPECIAL ISSUES OF JBIS

A new series of *JBIS* will appear in 1979 devoted to the scientific and educational aspects of space developments. It is expected that these topics will be of particular interest not only to teachers in schools and colleges, but to many members also.

There are many areas of interest. Opening issues will develop the application of basic mathematical and physical concepts to actual design examples of satellites and launch vehicles. Another will be the growing influence of satellites upon education in remote areas and developing countries e.g. by direct broadcast radio and TV.

Two Members of the Council have been appointed Joint Co-Editors of the proposed issues:

PETER J. CONCHIE and GORDON J. N. SMITH.

Both have extensive experience in the space field and are particularly keen to see increasing cooperation between the industrial and educational areas.

Suggestions for material to be included in the new issues as well as proposals for articles, news items, etc. should be sent direct to the Executive Secretary.

All material for publication must be in English. There are no requirements as to length. Other information of interest to potential authors will be found in the notes entitled "Guidance for Authors" on the inside back page of every issue of *JBIS*.

BIS DEVELOPMENT FUND APPEAL

In 1979 the Society's finances will be under very heavy pressure as payments become due for construction work and equipping the building. Every extra bit of income is important to the Society at the present time and any contribution which you feel able to make will be immediately applied to this urgent and vital work.

Please include a donation to the BIS Development Fund Appeal when completing your subscription renewal form. Whatever you can give will definitely count.

Please give generously.

TOTAL TO 31 OCTOBER 1978

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SPACEFLIGHT

A Publication of The British Interplanetary Society

Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

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CONTENTS

COVER

Enthusiasm for Space runs high throughout the Communist world after the huge success of the multiple dockings of manned Soyuz and unmanned Progress supply craft with the Salyut 6 space station. *Top*, the record-breaking Soviet cosmonauts Vladimir Kovalyonok (left) and Alexander Ivanchenkov who boarded the station on 17 June. *Below*, Soyuz 31 cosmonauts Valery Bykovsky and Sigmund Jähn – the first East German to fly in space – before their mission began on 26 August. Earlier visitors to Soyuz 6 included mixed Russian and Czechoslovakian and Russian and Polish crews. *Right*, Soyuz 31 is prepared for launching at Tyuratam.

Top, Novosti Press Agency; others Panorama DDR/Zenfralbild

MILESTONES

August

2 *New China News* publishes first photograph of launch of a Chinese ballistic missile "by a unit of the Chinese People's Liberation Army."

3 Astronauts Dr. Owen K. Garriott and Dr. Robert A. Parker are named by NASA as Mission Specialists for Spacelab 1 mission scheduled for the early 1980's.

9 Four U.S. scientists are named by NASA to serve as Payload Specialists during Spacelab 2 mission scheduled for 1981: Dr. Loren W. Acton, research scientist at the Lockheed Palo Alto Research Laboratory; Dr. John-David F. Bartoe and Dr. Dianne K. Prinz, research physicists at the U.S. Naval Research Laboratory, Washington D.C., and Dr. George W. Simon, chief of solar research branch, Air Force Geophysics Laboratory with permanent duty location at the Sacremento Peak Observatory, Sunspot, New Mexico.

15 Royal Aircraft Establishment, Space Department, predicts that Skylab could decay from orbit as early as May 1979.

17 *Novosti* reveals that the Salyut 6 cosmonauts have studied heart contractions and the reaction of their cardiovascular systems to exercises on the velo-ergometer "space bicycle" with the Polinom 2M and Beta apparatus. They also carried out a biomedical experiment "to study the change in the composition of the air within the space station." They continued experiments with the Splav furnace and Kristall kiln including a Soviet-Polish experiment 'Sirena' in the latter to obtain semiconductor materials based on cadmium, selenide, gallium arsenide and indium antimonide.

17 Progress 3 automatic freighter separates after 12 days from Salyut 6/Soyuz 29 under joint control from the ground and cosmonauts. *Novosti* reports: "With Progess 3 undocked and flying independently further tests on its equipment and systems were made."

24 Progress 3 is made to re-enter atmosphere and burn up over Pacific Ocean.

26 Soviets launch Soyuz 31 from Tyuratam at 17.51 hrs (Moscow time) with cosmonauts Col. Valery Bykovsky of USSR and Air Force Lt. Col. Sigmund Jähn of German Democratic Republic. After a correction manoeuvre orbit parameters were 271 x 326 km x 51.6 deg; period 90.2 min.

27 Soyuz 31 docks with Salyut 6/Soyuz 29 combination. Experiments include materials prepared by scientists of USSR and GDR – medical, biological and technological, research into physical processes and phenomena in Earth's atmosphere and also visual observations and photography using MKF-6M multi-spectral camera of different parts of Earth's surface and world's oceans in the interests of studying natural resources.

28 Four Salyut 6 cosmonauts start working together at 12.30 hors (Moscow time); their working day ends at 23 hrs. The Soyuz 31 crew made cardiovascular checks using onboard equipment. They also studied materials under micro-gravity using the Splav and Kristall apparatus.

28 NASA admits there is "only 50/50 chance of launching Space Shuttle" into orbit in September 1979.

[Continued overleaf

September

3 Soyuz 31 cosmonauts Bykovsky and Jähn in Soyuz 29 re-entry module soft-land 140 km (87 miles) south-east of Dzhezkazgan. They brought to Earth results obtained in the following experiments devised by scientists of the USSR and GDR: *Symoka* – photography of Earth by MKF-6M camera system. *Berolina* – growth of rare crystals in state of weightlessness. *Audio* – testing by means of highly sensitive equipment of a man's ability to distinguish the most subtle nuances of sound in outer space. *Vremya* – obtaining new data about man's ability to react speedily in space to commands given to him by an operator or a machine. *Reporter* – research into the conditions of photography inside spaceships and testing of various types of photographic film.

4 Cosmos 1028, possibly a new type of Soviet reconnaissance satellite, returns re-entry capsule after a month in orbit.

6 First test of Orbital Manoeuvring Subsystem (OMS) engine is completed at NASA's test facility at White Sands, New Mexico. Engine which included standard OMS pod components, tanks and feed pipes, ran for scheduled 10 seconds.

9 Soviets launch Venera 11 from Tyuratam using parking orbit techniques (orbit 177 x 205 km x 51.54 deg) with the aim of continuing scientific exploration of Venus. Station is due to reach the environs of the planet in December. *En route* apparatus designed by Soviet and French specialists will investigate solar wind, cosmic rays, UV and X-rays and gamma rays in outer space.

11 Second High Energy Astronomy Observatory (HEAO-B) leaves TRW's Redondo Beach, California, facility for Cape Canaveral. The satellite, scheduled to be launched in mid-November, will search for objects emitting radiation in the invisible, high energy universe. Five X-ray instruments on the 6,824 lb (3.095 kg), 22 ft (6.7 m) long observatory will use a 12.5 ft (3.8 m) telescope to examine such objects as the Crab Nebula and Circinus X-1, a black hole candidate. *(HEAO 1, launched in August 1977, is completing an extended mission to map the high energy sky. A third HEAO will be launched next year. Ed.).*

14 Soviets launch Venera 12 from parking orbit *en-route* to Venus. Spacecraft is similar to Venera 11.

16 Japan launches 70 kg (154 lb) Exos B 'Jikiken' scientific satellite by Mu-3H three-stage rocket from Uchinoura Space Centre, Kagoshima, Kyoshu Island. Orbit ranges between 230 x 30,588 km.

20 At 09.17 hrs (Moscow time) cosmonauts Vladimir Kovalyonok and Alexander Ivanchenkov break record for longest manned space flight of 96 days 10 hours set by their predecessors aboard Salyut 6 Yuri Romanenko and Georgi Grechko on 16 March 1978.

20 NASA announces that a flight-configured Space Shuttle Main Engine has exceeded 5,000 seconds of operation in test firings at the Agency's test facility in Bay St. Louis, Miss.

21 At 21.17 hrs (Moscow time) cosmonauts Kovalyonok and Ivanchenkov celebrate 100 days in orbit. Professor Nikolai Gurovsky, space doctor, says he is fully satisfied with cosmonaut's health. Professor Oleg Gasenko, another space doctor, has stated that 120 days is the present limit for man in space. The cosmonauts had just completed more technological experiments using the Kristall furnace. They had also been using the BST-IM telescope to study the Earth's horizon.

26 *Tass* announces that carrier rockets will be launched in the Soviet Union from 28 September to 10 October into areas of the Pacific Ocean with a radius of 50 n. miles centred 40°N, 159° 20′ E and 46°50′ N, 150°40′ E. Ships are advised not to enter these areas and aircraft the airspace above them during 0 to 6 hrs and 22 to 24 hrs local time.

27 *Tass* announces that Pacific target areas specified above will be free to shipping and air traffic from 29 September.

October

1 President Carter during a visit to Kennedy Space Center, Florida, reveals that American reconnaissance satellites have contributed immensely to international security and are an "important factor" in monitoring arms control agreements. Date marks the 20th anniversary of the foundation of NASA. Congressional Space Medal of Honor is awarded to six astronauts: Neil A. Armstrong; Frank Borman; Charles Conrad, Jr.; John H. Glenn, Jr.; Virgil I. Grissom (posthumous), and Alan B. Shepard, Jr.

5 *Novosti* reports that cosmonauts Kovalyonok and Ivanchenkov have taken 18,000 photographs of Earth since they began their work in space. Dr. Heinz Kautzleben, director of Central Institute for Earth Physics, Berlin, GDR, says whereas the Carl Zeiss MKF-6 multispectral camera tested on board Soyuz 22 was designed to work for only 8 days in orbit, the modified version MKF-6M is meant to function for two years. From a height of 250 km each photograph covers an area of about 115 x 165 km. When exposed film has been returned to Earth photos are examined by the Zeiss MSP-4 multispectral projector. Photos currently taken from Salyut 6 from 350 km altitude cover an area of 160 x 230 km. Sigmund Jähn, the East German cosmonaut, at the end of a tour of the GDR in Berlin, showed photos he had taken during the undocking of Soyuz 29 with a 35 mm camera. The German cosmonaut said he had two cameras – a Pentacon-6 and a Praktica EE2 – the latter being used mainly for photography within the station.

5 *Novosti* reports that Venera 11 should reach Venus on 25 December and Venera 12 on 21 December. On 25 September Venera 11 had travelled 5.5 million km and Venera 12 4.1 million km.

6 Progress 4 docks with Salyut 6 at 0.400 hrs (Moscow time).

7 *Soviet Weekly* quotes Professor Nikolai Gurovsky, a leading Soviet medical scientist, as saying that Western reports that the USSR was preparing an experiment in which a woman would give birth to a baby in space were "premature." Such speculations, he said, "were years ahead of the facts." What was being planned was the incubation in a Earth satellite of the fertilised eggs of a bird – the Japanese quail was a likely candidate

[Continued on page 419

APOLLO AND ZOND - RACE AROUND THE MOON

By Nicholas L. Johnson*

Introduction

Ten years ago on Christmas Eve like 20th century wise men the Apollo 8 astronauts brought humanity a gift of hope and renewal during their live telecast from lunar orbit. In the euphoria and introspection which followed this magnificent first voyage of men to the vicinity of the Moon, the intense drama and suspense of the events of the past year faded into obscurity. For all intents and purposes the space race – and indeed it was a race – ended in December, 1968, with the completion by astronauts Borman, Lovell, and Anders of mankind's first circumlunar flight. But what of the Soviets? Were they desperately trying to send a manned Zond spacecraft on a lunar fly-by prior to Apollo 8 or were they only trying to lure the US into a dangerous and possibly unsuccessful flight to the Moon? Was Apollo 8 born in desperation to beat the Soviets in response to the flights of Zond 5 and Zond 6? Just how closely did the world actually come to hearing not American but Russian voices describing man's first personal glimpse of that grey, lifeless globe?

The Race Begins

The manned lunar landing programmes of both the US and USSR were dealt near-fatal blows in early 1967 with the Apollo 1 and Soyuz 1 disasters. The Soviets had jumped to a quick lead in the race to the Moon with their highly successful Vostok (1961-1963) and Voskhod (1964-1965) manned missions. Meanwhile the Americans who began slowly with the less ambitious Mercury programme (1961-1963) soon closed the gap and edged slightly ahead with the brilliantly executed Gemini flights (1965-1966). By New

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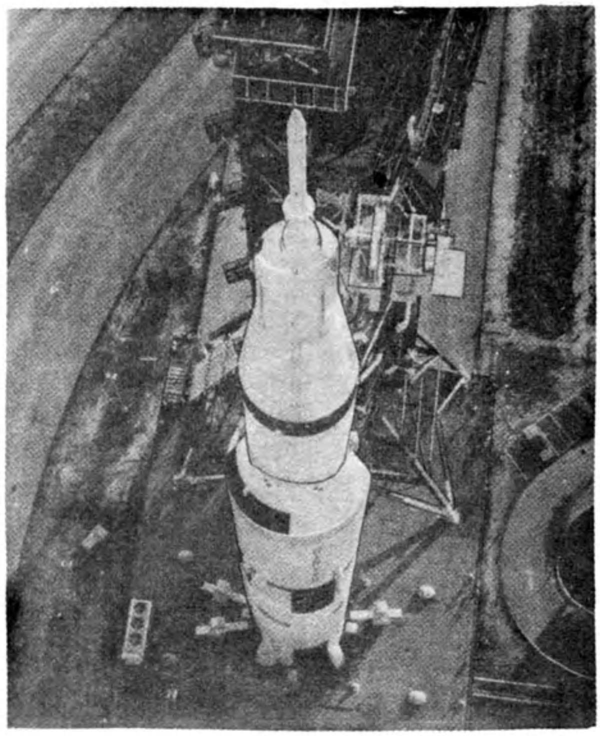
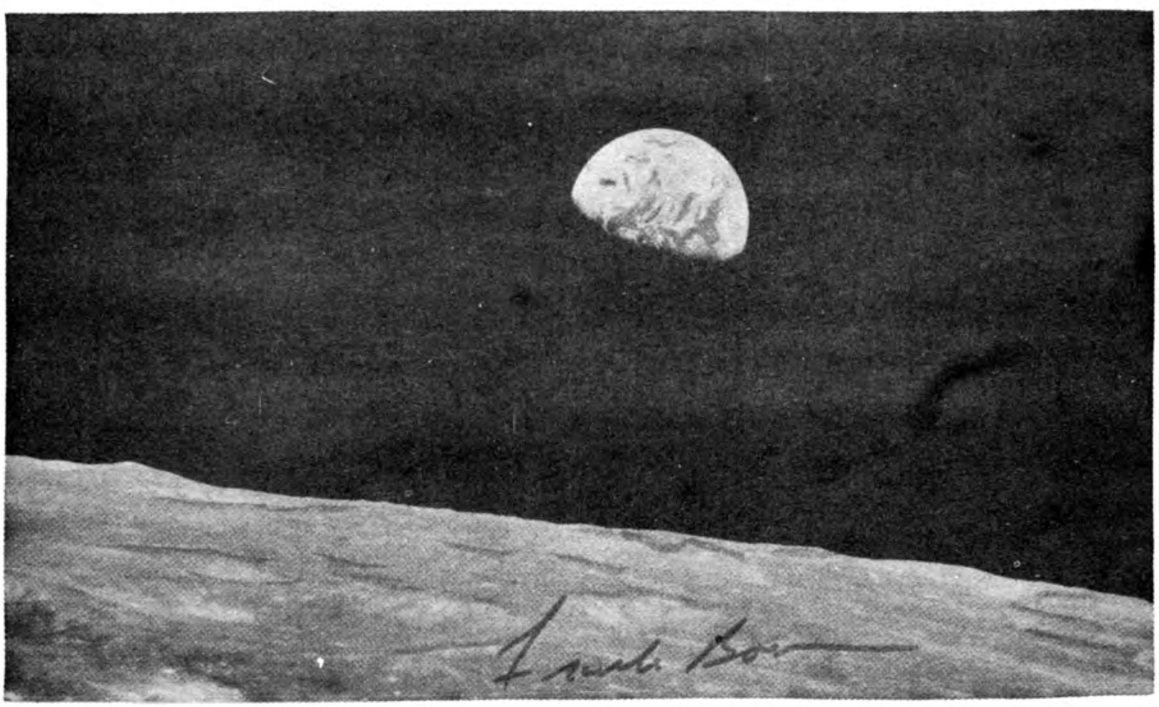
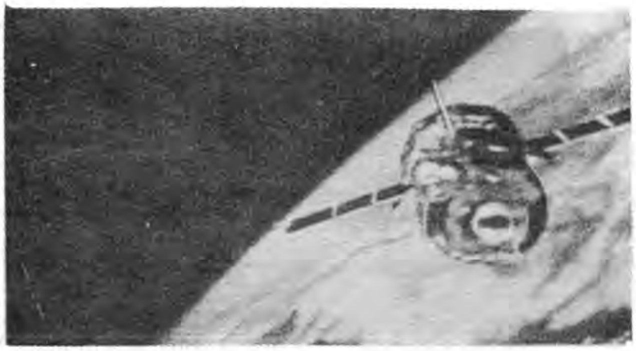


APOLLO 8 ON THE MOVE. Saturn 5, topped with the spacecraft, moves out from the Vehicle Assembly Building at Cape Canaveral on its way to Complex 39 on 9 October 1968.



APOLLO TRIUMPH. The thrilling spectacle of a half-Earth that greeted the Apollo 8 astronauts as they rounded the Moon in December 1968. The mission – which included 10 lunar orbits – was flown by Frank Borman (commander), James A Lovell, Jr., and William A. Anders.

National Aeronautics and Space Administration



The Soyuz spacecraft (shown here) has roots buried deep within the Cosmos programme. Did its lineage also include a variant for manned circumlunar flight?

Novosti Press Agency

Year's day of 1967 both countries were rapidly preparing the new generation spacecraft needed to land men on the Moon and safely return them to Earth. Following the launch pad fire which asphyxiated astronauts, Grissom, White, and Chaffee in January, and the spacecraft crash which killed cosmonaut Komarov on the maiden flight of Soyuz in April, it became clear that the first country to recover from its own mishap would probably have the decisive advantage. While manned spaceflights would necessarily be postponed at least one year until the causes of the accidents could be pinpointed and corrected, much could still be done in developing the necessary lunar spacecraft hardware.

The Soviets were the first to move. Only six months after the death of Komarov, Cosmos 186, an unmanned version of Soyuz, was launched into a low Earth orbit at the new man-related orbital inclination of 51.7 degrees. Three days later Cosmos 188 was placed in orbit with such accuracy that the two spacecraft were initially only 24 km apart with a relative velocity of 25 mps. Immediately, Cosmos 186 assumed the active role in closing this distance. Within approximately one hour of the launch of Cosmos 188 the two remorely controlled stations had successfully completed the world's first automatic rendezvous and docking. After remaining docked for 3.5 hours Cosmos 186 and Cosmos 188 separated and were recovered on 31 October and 2 November, respectively.

Soviet spokesmen were quick to point out that this technique of automatic rendezvous and docking was valuable in not only the construction of space stations, but also the assembly of interplanetary spaceships [1, 2]. Due to the failure of the Soviets to perfect a launch vehicle larger than the Proton carrier capable of landing men on the Moon and returning them, the possibility of assembling a lunar spacecraft in Earth orbit was considered likely both then and now [3, 4, 5].

However, exactly one week after the return of Cosmos 188, the United States scored an even more impressive achievement. On 9 November 1967 the first Saturn V/Apollo launch vehicle/spacecraft combination flew a spectacularly flawless mission in an "all-up" test rarely seen in rocket development. Rather than perfect the Saturn V launcher stage by stage in an expensive and time-consuming programme, the maiden flight of the F-1 engine and complete first and second stages was accompanied by a live third stage and by operational Command and Service Modules on a taxing mission profile. George Mueller, Associate Administrator for Manned Space Flight at NASA, proposed the test in 1964 [6]. Besides the difficulties of adequately testing the Saturn V piecemeal, the United States could not have fulfilled President Kennedy's pledge to land on the Moon before 1970 without accelerating the already hectic pace of the Apollo programme [7, 8].

Following a textbook launch of the largest rocket the world had ever seen, the Saturn V third stage and Apollo spacecraft entered a 187 km circular orbit. After two revolutions the third stage was restarted, followed by separation and ignition of the Service Module propulsion engine which drove the Apollo spacecraft to an altitude near 18,000 km. Several hours later with the restart of the SPS engine the Apollo Command Module was hurled Earth-ward at a velocity of 40,000 km (to simulate a lunar return) to a perfect landing in the Pacific. The score now stood at US-1, USSR-1. The year 1968 was fast approaching, and it promised to be one of high competition and daring.

January of 1968 witnessed the end of both the US Surveyor and Lunar Orbiter programmes. On 10 January Surveyor 7 soft landed in the Crater *Tycho*, completing a programme of extensive close-up photographic and scientific analysis of the Moon prior to a manned landing. Just three weeks later on 31 January Lunar Orbiter 5 was sent crashing into the Moon upon completion of the lunar satellite programme which had charted mascons, photographed virtually all of the lunar surface, and had furnished detailed views of the potential Apollo landing sites. The next American spacecraft to the Moon would be manned.

On 22 January 1968 the first orbital test of the Apollo Lunar Module (LM), launched by a Saturn IB and designated Apollo 5, was conducted. The LM sans landing legs completed six revolutions about the Earth during which time both the descent and ascent stages were tested repeatedly. Although the firings were plagued by computer control malfunctions, the overall mission was considered a success and plans for a second unmanned test of the LM in June 1968 were cancelled [9, 10, 11].

While the second Saturn V scheduled to carry Apollo 6 was being prepared on Pad 39A at the Kennedy Space Center, the Soviet Union let it be known that she was far from out of the race. A Budapest dispatch on 22 February quoted the late cosmonaut Belyayev (Voskhod 2) as saying that the next step in the Soviet lunar programme was not a lunar landing, but a manned lunar orbit mission [12]. Eight days later a D-1-e launch vehicle left Tyuratam carrying the Zond 4 spacecraft. Zond 4 was the first deep space flight of the man-related Zond programme (Zonds 1-3 were scientific planetary probes) aimed at manned circumlunar and lunar landing missions.

A manned Soviet circumlunar flight had been seriously predicted for quite some time. Although the reported attempt to circumnavigate the Moon in October-November, 1967, on the 50th anniversary of the USSR [13, 14, 15] probably was postponed after Soyuz 1 and difficulties with the D-1 launch vehicle, rumours still indicated a Soviet manned lunar fly-by in 1968 [16]. Just four days before the Budapest dispatch John N. Wilford of the *New York Times* had predicted the Soviets would resume Earth orbital manned flights by May and would attempt a manned circumlunar flight in the fall [17]. Finally, on 25 February another Soviet cosmonaut, this time Valery Bykovsky (Vostok 5 and later Soyuz 22) again raised the question of circumlunar flights in a Hungarian Army newspaper, suggesting animals (perhaps even offspring of Laika) would probably precede men around the Moon on test flights [18].

Zond 4 at first appeared to be a precursor of just such a flight although the Moon was positioned 180 degrees away from the desired location for a true circumlunar flight. Whether or not Zond 4 was to fly a highly elliptical Earth orbit and test the reentry characteristics of the Zond command module at lunar return velocities is unknown. Two Soviet historical works [19, 20] list Zond 4 as having entered a heliocentric orbit, while Ley [21] asserts that the spacecraft failed to leave Earth orbit and RAE data suggest

that Zond 4 may have reentered the Earth's atmosphere after a flight of 6.8 days. Furthermore Smolders [22] believes the probe landed in the Indian Ocean on 9 March after a trip around a phantom Moon, and an aerospace periodical in November, 1968, claimed Zond 4 went into a highly elliptical orbit with an apogee of 350,000 km and was destroyed upon reentry 9 August [23]. Finally, Woods has recently [24] revised his opinion that Zond 4 may have been perturbed into a heliocentric orbit [25] and now believes the trajectory was direct.

The fate of Zond 4 is of the utmost interest since a successful mission might have altered the subsequent course of the history of space exploration – at least as far as the first manned circumlunar flight is concerned. After the initial announcements of the launch of Zond 4, the Soviets fell strangely silent. A comparison of the Zond 4 launch announcement with that issued for Zond 5 in September, 1968, shows a verbatim similarity with the exception of two sentences added to the Zond 5 announcement before the last line. These sentences read

> *Steady radio communications are being maintained with the probe Zond 5. According to telemetric data, all the systems and assemblies on board and the scientific equipment are functioning normally [26].*

Those familiar with Soviet launch announcements readily recognize this phrase. Although it was also included in the subsequent Zond 6-8 press releases, it was absent from the Zond 4 report. Therefore, one may wonder whether Zond 4 experienced a major communications, power, or equally crippling problem early in flight. The Soviets may be as much in the dark about precisely what happened to Zond 4 as is the rest of the world.

The Pace Quickens

Next, it was the United States' turn to watch a carefully prepared mission flirt with disaster. Plans had already been formulated to man the third Saturn V for an Earth orbital mission if the second Saturn V carrying Apollo 6 was successful [27, 28]. This was a far cry from the originally estimated ten Saturn V's needed to man-rate the huge lunar rocket [29]. It was this planned programme flexibility (carried over from Gemini) which allowed each successive flight to build upon the successes and failures of its predecessor and that ultimately was responsible for the entire superbly successful Apollo programme.

At 0700 local time on 4 April Apollo 6 lifted-off with the same thunder and blinding light of Apollo 4. Again the flight at first appeared picture perfect when the warning lights began to blink. With only 23 seconds left in the burn of the first stage (125 seconds elapsed time) severe pogo oscillations were felt throughout the vehicle structure. Soon after, external structural panels unexpectedly fell away from the Lunar Module adapter section. Then to the utter dismay of the flight engineers, during the second stage firing the No. 2 J-2 engine shut down prematurely, followed immediately by shutdown of the No. 3 engine. With the aid of the three remaining J-2 engines of the second stage the launch vehicle continued to climb until the third stage took over, propelling the Apollo spacecraft to a 395 km x 172 km orbit (instead of the planned 175 km circular one). Finally, when the third stage J-2 engine was signalled to restart on the second orbit in a repeat of the Apollo 4 mission profile, the engine refused to ignite.

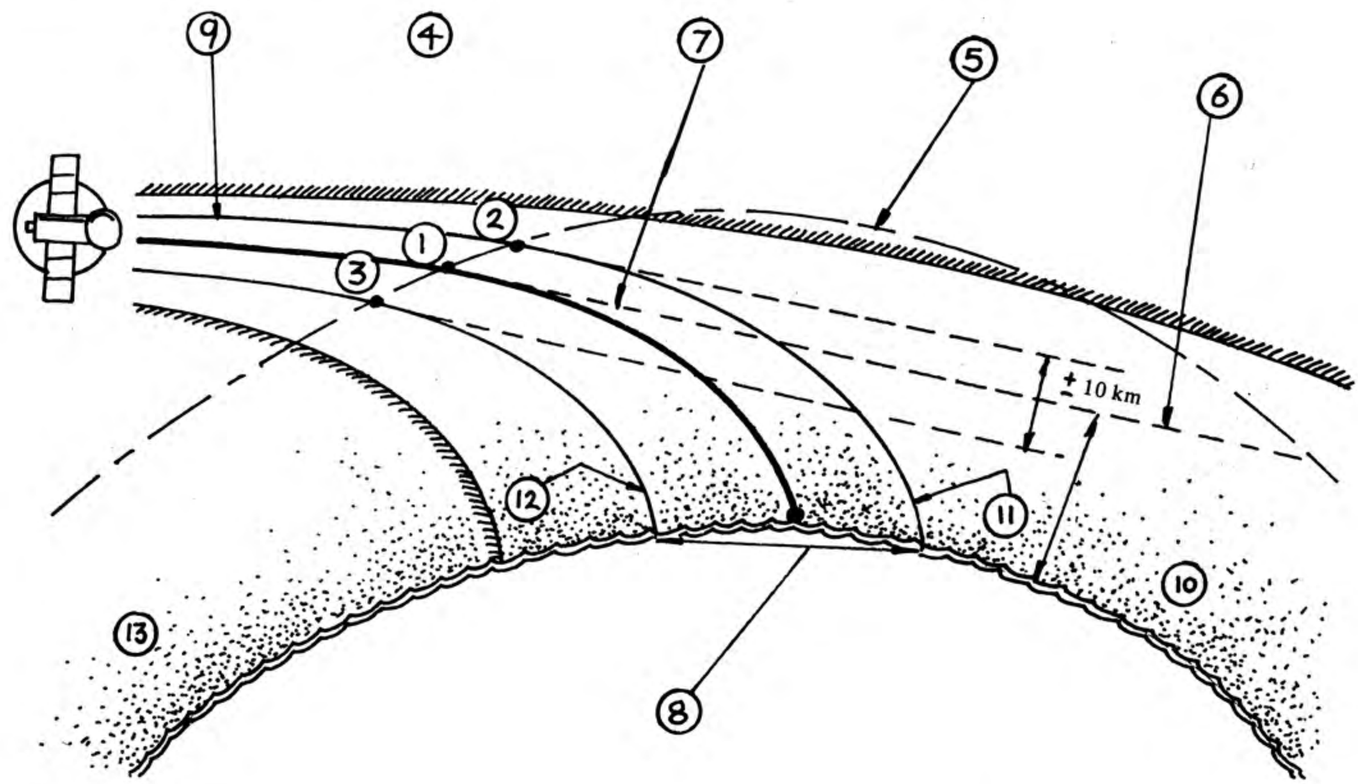
The Apollo 6 flight was quickly salvaged by relying on the power of the big Service Module propulsion engine to lift the Command Module to an altitude of over 22,000 km from which it reentered the Earth's atmosphere at slightly under the programmed velocity to a safe splash down in the Pacific. Analysis of the Saturn V malfunctions was begun immediately with an eye still on manning the third Saturn V by the end of the year.

As if to accentuate the growing intensity of the race to the Moon, the Soviet Union delivered a one-two punch immediately after the marginal Apollo 6 flight which at least gave the appearance of sending the NASA organization reeling. Luna 14, the fourth Soviet lunar satellite and last of the second generation Luna probes, entered lunar orbit on 10 April after an Earth launch three days earlier. In conjunction with the three previous Soviet lunar satellites (Lunas 10-12) and the two successful lunar soft landers (Lunas 9 and 13), Luna 14 completed the unmanned photographic and scientific research necessary to suuport a manned lunar landing in much the same way as the Surveyor and Lunar Orbiter missions had been terminated a few months before.

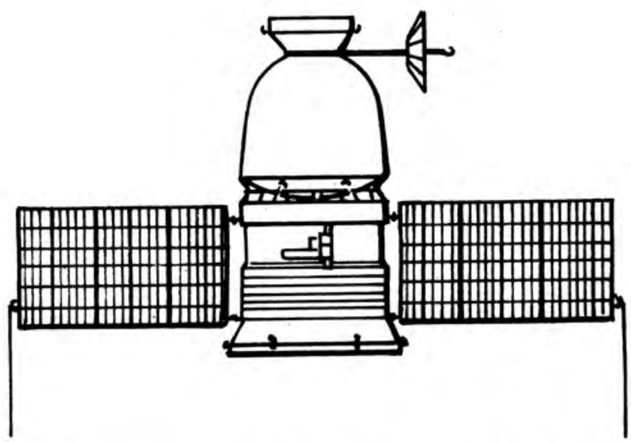
Although the flight of Luna 14 was in itself of no immediate concern to US officials, the accomplishment of a second automatic rendezvous and docking in Earth orbit on 15 April by two unmanned spacecraft believed to be prototypes of lunar spaceships seemed to point to a renewed effort by the Soviets to get their lunar programme back on schedule [30]. Almost 24 hours after the launching of Cosmos 212, Cosmos 213 sped away from the Baikonur cosmodrome, setting up a chase which culminated 47 minutes later half-way around the world in a televised docking. In contrast to US techniques, the USSR again launched the "active" chase vehicle first while the "passive" target vehicle was launched later. The orbital parameters of the docked pair resembled those of Cosmos 186/188 and Soyuz 1, indicating the man-related nature of the experiment. Mechanical and electrical coupling between Cosmos 212 and Cosmos 213 was maintained for three hours and fifty minutes. Following separation, the two unmanned Soyuz spacecraft continued in orbit to test various on-board systems. Each vehicle was led through a series of orbital manoeuvres during the next few days with recovery of the command modules of Cosmos 212 and Cosmos 213 occurring on 19 and 20 April, respectively.

The significance of the Zond 4, Luna 14, and Cosmos 212-213 missions taking place in little over a month was underscored between 24 and 29 April when Apollo programme director, General Samuel Phillips formally recommended and NASA Administrator James Webb approved the plan to man the third Saturn V on an Earth orbital mission in late 1968 [31, 32]. This decision was made despite the major problems encountered by the Apollo 6 Saturn V. Credit had been given to the Saturn V for being able to safely place Apollo 6 into orbit with two of the five second stage engines shut down. No difficulty was foreseen in elminating the pogo oscillations (of the type which plagued the Gemini-Titan launch vehicle) or faulty manufacture of the LM adapter segment. Finally, restart of the S-4B third stage, which failed on Apollo 6, was planned to take place after separation of the Apollo 8 spacecraft and hence would have no direct effect on this manned mission [33].

With NASA obviously escalating the pace of the Apollo programme with an eye on actually meeting the self-imposed 1969 deadline, the Soviets were in the uncharacteristic position of playing catch-up. A further indication of the USSR's decision to remain in the race came with an announcement on 18 May that the USSR would conduct rocket tests from 20 May to 30 June with splash down in the Pacific Ocean. The announced series of tests was reminiscent of the Pacific testing carried out in January 1960 only a few months before the first unmanned Vostok spacecraft flew. The purpose of these 1968 flights was to conduct "further tests of the landing system of space apparatuses" [34]. There was also speculation that a new powerful



ZOND 5 RE-ENTRY AND LANDING SEQUENCE. 1. Calculated re-entry point into Earth's atmosphere. 2. Point of entry to atmosphere for landing on the far border of the landing area. 3. Point of entry to atmosphere with landing at near border of landing area. 4. Region of outer space. 5. Effective limit of atmosphere. 6. Trajectory neglecting effect of atmosphere. 7. Ballistic descent trajectory. 8. Calculated splashdown area. 9. Re-entry corridor. 10. Conventional perigee height. 11. Upper border of re-entry corridor. 12. Lower border of corridor. 13. Region of unacceptable g-loading. *Legends are those supplied by Soviet authorities.*



Artist's impression of a Zond circumlunar spacecraft, based on a Soviet drawing.

Bill Hobson

launch vehicle would be tested along with the water recovery system. Four months later the Soviet Union did indeed conduct its first water recovery for a returning spacecraft – the unmanned Zond 5, following its historic first circumlunar flight.

Oddly enough, on the very day that the Soviet Pacific testing was announced, former astronaut Scott Carpenter, speaking before a college audience, predicted the US might attempt a manned circumlunar flight in the fall to prevent a Soviet crew from capturing the glory of the world's first lunar mission [35]. In the light of subsequent events, it is impossible to determine how much Carpenter was speaking from his own opinions or from discussions which had taken place at NASA.

The Goal is Set

The summer months of June and July passed quickly and quietly. Like the calm before a storm, both countries were silently gearing up for one last effort to send men to the Moon before the end of the year. Strangely, a manned circumlunar flight had now become the challenge to meet. Perhaps an actual lunar landing still seemed too far off with the US yet to fly a manned Apollo and experiencing problems with the Lunar Module and with the USSR failing to get the heavy G-1 rocket off the ground. Or perhaps both countries sensed whichever nation flew first around the Moon would also make the first landing.

When George M. Low accepted the position of Apollo spacecraft programme manager on 3 April 1967 the US manned space programme was at low-ebb. Fresh and dramatic thinking was essential if the US was to prevent what the Soviets had grown fond of predicting – the first Apollo astronauts being greeted on the Moon by their Soviet counterparts. Apollo had come a long way under Low since the Apollo 1 fire. Now came the time to reap what he had so carefully sown.

The idea of a manned circumlunar flight without landing had lain relatively dormant in the US until early 1968 [36,

37] although plans were first proposed prior to President Kennedy's famous speech setting 1969 as a national goal for a manned lunar landing [38]. In late March, 1968, at least one circumlunar flight was again being considered before an attempted landing on the Moon. Now, June and July witnessed repeated technical problems with the Lunar Module which raised the question of further delays to the D (Apollo and LM) mission scheduled for Apollo 8. The momentum of Apollo was periously close to being lost.

With the LM unable to fly until early 1969, Low proposed in early August, 1968 (more than a month before Zond 5), an option to send Apollo 8 sans Lunar Module on a lunar fly-by or lunar orbit mission in December [39]. The rationale for such a divergence from the carefully prepared Apollo schedule was considerable. If Apollo 8 was delayed until March, 1969 (an even further delay was still possible), only nine months would remain to conduct two more tests of Apollo (one high elliptical Earth orbit mission and one circumlunar flight) before attempting a lunar landing [40]. If problems arose on any of these flights a landing on the Moon in 1969 would be in jeopardy. Furthermore, the Lunar Orbiter series spacecraft had discovered and partially plotted large mass concentrations (mascons) located beneath the lunar maria. These mascons perturbed the lunar gravitational field and made lunar orbit navigation a delicate job. NASA wanted Apollo lunar orbit experience before committing men to a landing mission.

Low's proposal was quickly accepted by Robert Gilruth (Director of the Manned Spacecraft Center), Christopher Kraft (Manned Spacecraft Center Flight Director), General Phillips, and von Braun. However, Mueller, Webb, and President Johnson required a little more persuasion [41]. Finally, the goal was set – if Apollo 7 was a success and the Saturn V was ready, a lunar orbit mission was to be the target for Apollo 8 although a simple fly-by or even Earth orbital flight might be flown. The first public announcement of the possible circumlunar flight was made 19 August when crew and mission changes were revealed for Apollo 8 and 9 (McDivvitt, Scott, and Schweickart assumed the roles of the Apollo 9 crew now scheduled to fly the first Lunar Module in Earth orbit due to their extensive training and Borman, Lovell, and Anders shifted to fill the Apollo 8 slots) [42, 43].

One can only imagine the surprise which the Soviets must have felt upon hearing the daring plan of Apollo 8. They were nearing the final testing stage of a simple manned lunar fly-by for possibly late 1968 or early 1969. Zond by itself did not have the capability of entering lunar orbit and returning; but with the first Apollo mission to the Moon optimistically scheduled for late spring of 1969, the Soviets might still have had the prestige of sending the first men around the Moon. Now the game had changed. The Zond/Soyuz spacecraft and D-1-e booster had to be man-rated and ready before December! To Soviet scientists and politicians the United States must have seemed fool hardy indeed to even think of sending a three man crew into lunar orbit on the very second manned flight of a new spaceship and the first manned flight of the largest rocket in the world without having sent an unmanned spacecraft to the Moon on even a simply fly around pattern. The Americans had raised the ante. It was now up to the Soviets to call or fold.

Shortly after midnight (Moscow time) on 15 September 1968 a Proton launch vehicle lit up the night sky and roared off a pad at the Tyuratam cosmodrome. Sixty-seven minutes later its payload, Zond 5, was heading toward the Moon at 11 km/sec [44]. While Soviet spokesmen refused to reveal the purpose of the approximately 5,000 kg Zond 5, radio telescopes around the world were tracking the mysterious spacecraft with the hope of deciphering its mission at least in part. On 18 September Zond 5 dipped to within 1,950 km of the lunar surface, swung around the Moon, and started the return journey to Earth. Only on 20 September with Zond 5 fast approaching Earth again did the Soviets acknowlegde that Zond 5 had indeed circumnavigated the Moon [45]. In the evening of 21 September Zond 5 slammed into the Earth's atmosphere and began a fiery ballistic descent through a narrow (10-13 km) re-entry corridor. G-loads quickly increased to 10-16 g's while the temperature of the heat shield reached 13,000°C. Fourteen minutes later Zond 5 was floating intact in the Pacific Ocean after the USSR's first water recovery.

The Soviet Union had scored another impressive first in space exploration – the first true circumlunar flight (Luna 3 in 1959 was not recovered). NASA could only hope now that the Soviets would not send a manned Zond around the Moon before Apollo 8 could fly. However, there was one ominous footnote to the Zond 5 mission. A respected aviation and aerospace periodical [46] reported that a tape recording of a human voice reciting simulated instrument readings was played by Zond 5 near the Moon. This could only be interpreted as a test of communications systems for a follow-up manned flight [47].

While Zond 5 was still in space, NASA slowly began publicizing [48, 49] the flight plan for Apollo 8, assuming the upcoming Apollo 7 was successful. The highlight of the mission of course would be the ten orbits of the Moon on Christmas Eve. It was reported that astronaut training for the Moon orbiting mission was already underway before the Zond 5 flight [50]. With the return of Zond 5 came western predictions of imminent manned flights in Soyuz and Zond spacecraft [51]. For the first time the public at large became aware that a real race to the Moon was in progress.

T Minus Two Months

Three weeks after the return of Zond 5, Apollo 7 lifted off from Pad 39A at the Kennedy Space Center atop a Saturn IB rocket for an eleven day flight to thoroughly test the Apollo spacecraft systems. Unspoken was the thought that only a complete success would allow Apollo 8 to beat Zond to the Moon. But by the splash down of Apollo 7 on 22 October there was little doubt. The first US manned flight since Gemini 12 and the Apollo 1 pad fire was characterized by NASA as "flawless." Only a final review of the status of the Saturn V and of the flight of Apollo 7 was needed before a final decision on 11 November concerning Apollo 8 could be made. However, in the intervening three weeks the Soviet Union would attempt to solidify its manned lunar programmes and set the stage for a manned flight around the Moon.

The similarities of the US and USSR space programmes have always been a source of amazement. The successes and failures of both nations occur with uncanny parallels. Both manned space flight programmes had been placed in mothballs after the disasters of early 1967. Now within three days of the return of Apollo 7 astronauts, USSR cosmonauts were preparing to venture into space once more.

On 25 October an unmanned Soyuz 2 spacecraft was launched unannounced into an Earth orbit of 224 km by 185 km with an orbital inclination of 51.7 degrees. Approximately twenty-four hours later Soyuz 3, carrying Georgiy Beregovoy, left Tyuratam to rendezvous with Soyuz 2. For the first time Soviet space scientists had launched the target vehicle (Soyuz 2) prior to the chase vehicle (Soyuz 3).

Before Beregovoy had completed one revolution, he had manoeuvred his spacecraft to within at least 200 metres of Soyuz 2. Although it is normally assumed that Soyuz 2 and Soyuz 3 were intended to dock as well, Soviet spokesmen have generally refused to admit this. Following a period of station-keeping with Soyuz 2, Beregovoy pulled away to a distance of 565 km and repeated the rendezvous procedure.

After performing a variety of experiments both spacecraft were recovered – Soyuz 2 on 28 October and Soyuz 3 on 30 October. Despite the fact that the Gemini astronauts had performed similar and more difficult assignments almost three years before, the USSR was buoyed by this success, while the US waited for another space spectacular. It came sooner than anyone thought.

On 10 November, eleven days after Beregovoy's return, Zond 6 was launched on what at first appeared to be a repeat performance of the Zond 5 space flight. Following Zond 5's footsteps, Zond 6 whipped around the Moon at an altitude of 2,420 km on 14 November and began the long journey home. Whereas Zond 5 had made a simple ballistic re-entry, Zond 6 was programmed to attempt the much more difficult skip-lob approach. After two course corrections on the return leg, Zond 6 entered the Earth's atmosphere at 11 km/sec, slowed to 7.6 km/sec and then bounced back into space before plunging again into the atmosphere for a landing on Soviet territory.

The re-entry of Zond 6 was typical of that which returning cosmonauts would have to follow. A ballistic re-entry would place excessive g-loads on the cosmonauts and would prevent landing on Soviet territory. These problems had now been solved by Zond 6 [52].

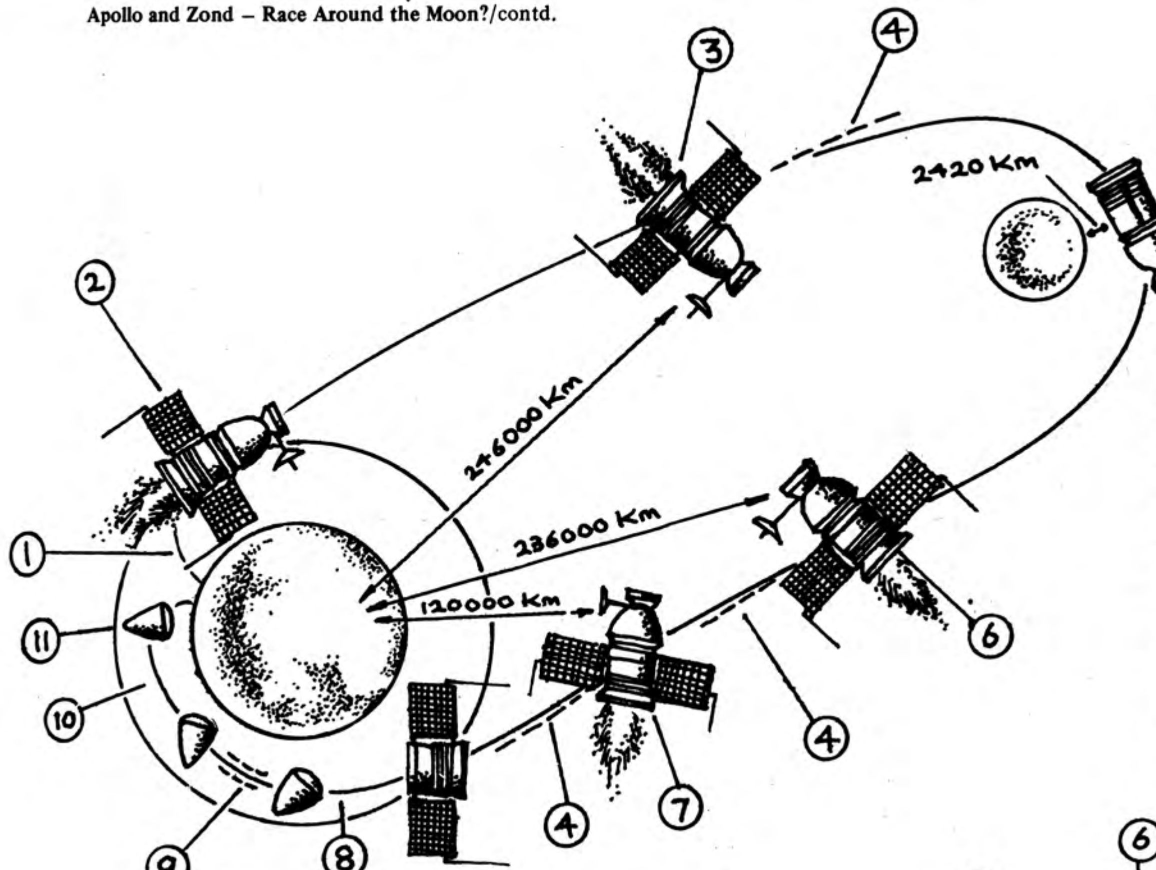
It was during the Zond 6 flight that the Soviets finally announced that the Zond spacecraft was capable of carrying a human crew and was part of a manned lunar programme [53-56]. Also for the first time, diagrams depicting the flight profile of a Zond spacecraft bore a remarkable resemblance to a Soyuz spacecraft sans orbital compartment. The Zond 5 diagrams all employed drawings of the much smaller Zond planetary probes (Zond 1-3). The two impressive successes of Zond 5 and Zond 6 along with the Soyuz 2-3 mission gave a burst of confidence to the Soviet space programme and heightened public speculation of a Soviet manned circumlunar flight before the planned Apollo 8 Moon mission [57].

Related Space Flights (Oct 67 - Dec 68)

US		USSR
	Oct	
Apollo 4	Nov	Cosmos 186/188
	Dec	
Surveyor 7 Apollo 5 Lunar Orbiter 5	Jan	
	Feb	
	Mar	Zond 4
Apollo 6	Apr	Luna 14 Cosmos 212/213
	May	
	Jun	
	Jul	
	Aug	
	Sep	
Apollo 7	Oct	Zond 5 Soyuz 2/3
	Nov	Zond 6
	Dec	
Apollo 8		

Related Events (Oct 67- Dec 68)

Date	Event
27-30 Oct 67	*Cosmos 186 and 188. First unmanned automatic rendezvous and docking on 30 October 1967.*
9 Nov 67	Apollo 4. First flight of Apollo/Saturn V in "all up" test. Flawless mission.
10 Jan 68	Surveyor 7. Last unmanned Surveyor soft lands on the Moon, completing extensive photographic and scientific analysis of Moon prior to manned lunar landing.
22 Jan 68	Apollo 5. First test flight of Lunar Module launched by Saturn IB. Although minor problems developed, mission was called a success and a second unmanned LM test was cancelled.
31 Jan 68	Lunar Orbiter 5. Last Lunar Orbiter mission ended with intentional crash of Lunar Orbiter 5 into Moon. Photographic survey of potential Apollo landing sites completed.
18-25 Feb 68	*Several reports surface around the world indicating USSR is planned a manned circumlunar flight.*
2 Mar 68	*Zond 4. First flight in deep space of unmanned Zond intended for use in Soviet lunar landing programme. Apparent failure.*
4 Apr 68	Apollo 6. Second flight of Apollo/Saturn V. Second and third stages experience major failures, but flight is partial success.
10 Apr 68	*Luna 14. Fourth Soviet lunar satellite enters orbit about the Moon. Last of the second generation Luna probes.*
14-15 Apr 68	*Cosmos 212 and 213. Second unmanned automatic rendezvous and docking on 15 April 1968.*
29 Apr 68	NASA makes final decision to launch the next Saturn V with Apollo crew on board.
20 May 68	*Soviets begin rocket testing period with Pacific splashdown. Believed to be related to resumption of manned space flight with water recovery and/or new heavy launch vehicle.*
19 Aug 68	First publuc announcement by NASA of possible Apollo 8 lunar orbit mission.
15-21 Sep 68	*Zond 5. First circumlunar flight and recovery. First Soviet water recovery.*
11-22 Oct 68	Apollo 7. First manned Apollo mission. Launched by Saturn IB with no Lunar Module. First US manned space flight since Apollo 1 disaster in January 1967.
25-30 Oct 68	*Soyuz 2 and 3. Rendezvous of manned Soyuz 3 with unmanned Soyuz 2. First USSR manned space flight since Soyuz 1 disaster in April 1967.*
10-17 Nov 68	*Zond 6. Second unmanned circumlunar flight. Employed sophisticated skip-lob re-entry to land on Soviet territory. First announcement that Zond spacecraft was capable of carrying a human crew.*
11 Nov 68	Final decision is made by NASA to attempt ten orbits of the Moon with Apollo 8.
1-12 Dec 68	*Reports hint of possible manned Zond circumlunar mission to be launched during this period.*
21-27 Dec 68	Apollo 8. First manned lunar mission. Completed ten revolutions about the Moon on Christmas Eve.



Flight plan of automated Zond 6 on Earth-Moon trajectory. Key: 1. Injection into intermediate orbit. 2. Trans-lunar injection. 3. First correction of trajectory. 4. Spacecraft flight trajectory without correction. 5. Flight around Moon. 6. Second correction of trajectory. 7. Third correction of trajectory. 8. Separation of landing module. 9. Descent into atmosphere; re-entry corridor. 10. Portion of (ballistic flight outside atmosphere. 11. Landing.

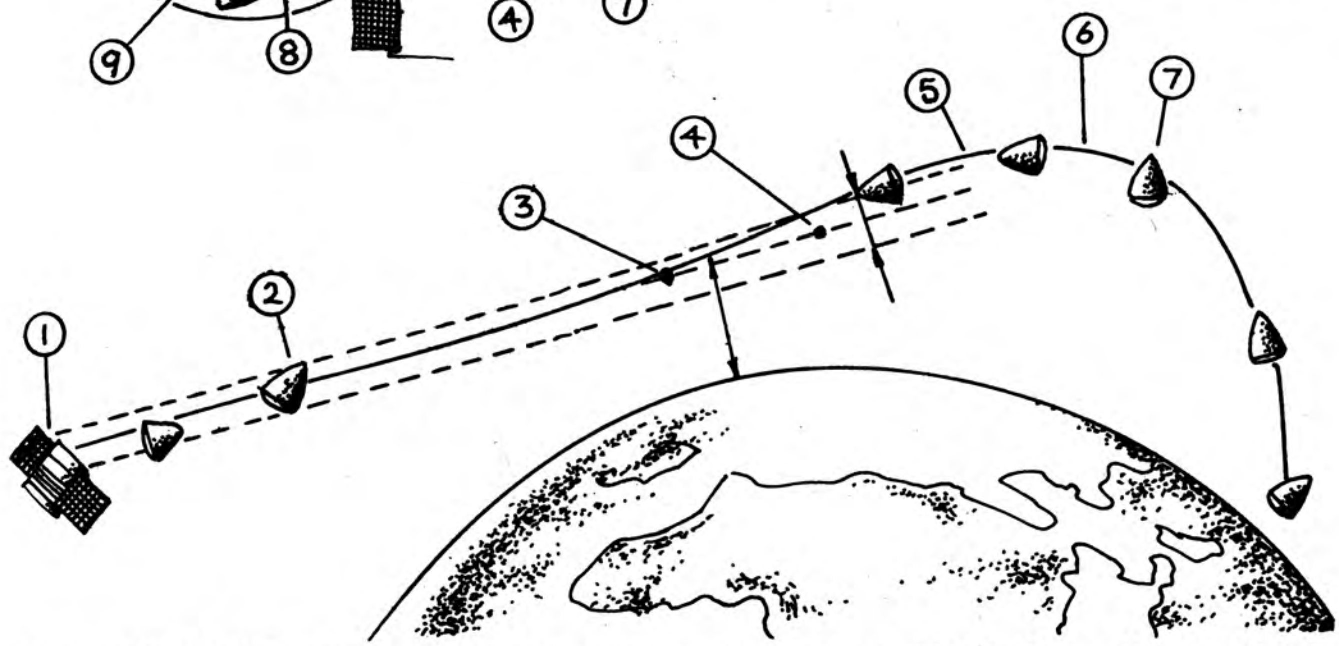


Diagram of Zond 6 re-entry manoeuvres. Key: 1. Separation of landing module from service module. 2. Stabilisation of landing module. 3. Re-entry corridor. 4. Flight trajectory neglecting atmosphere. 5. Effective limit of atmosphere. 6. Aerodynamic skip out of atmosphere (ballistic flight). 7. Return to atmosphere and landing.

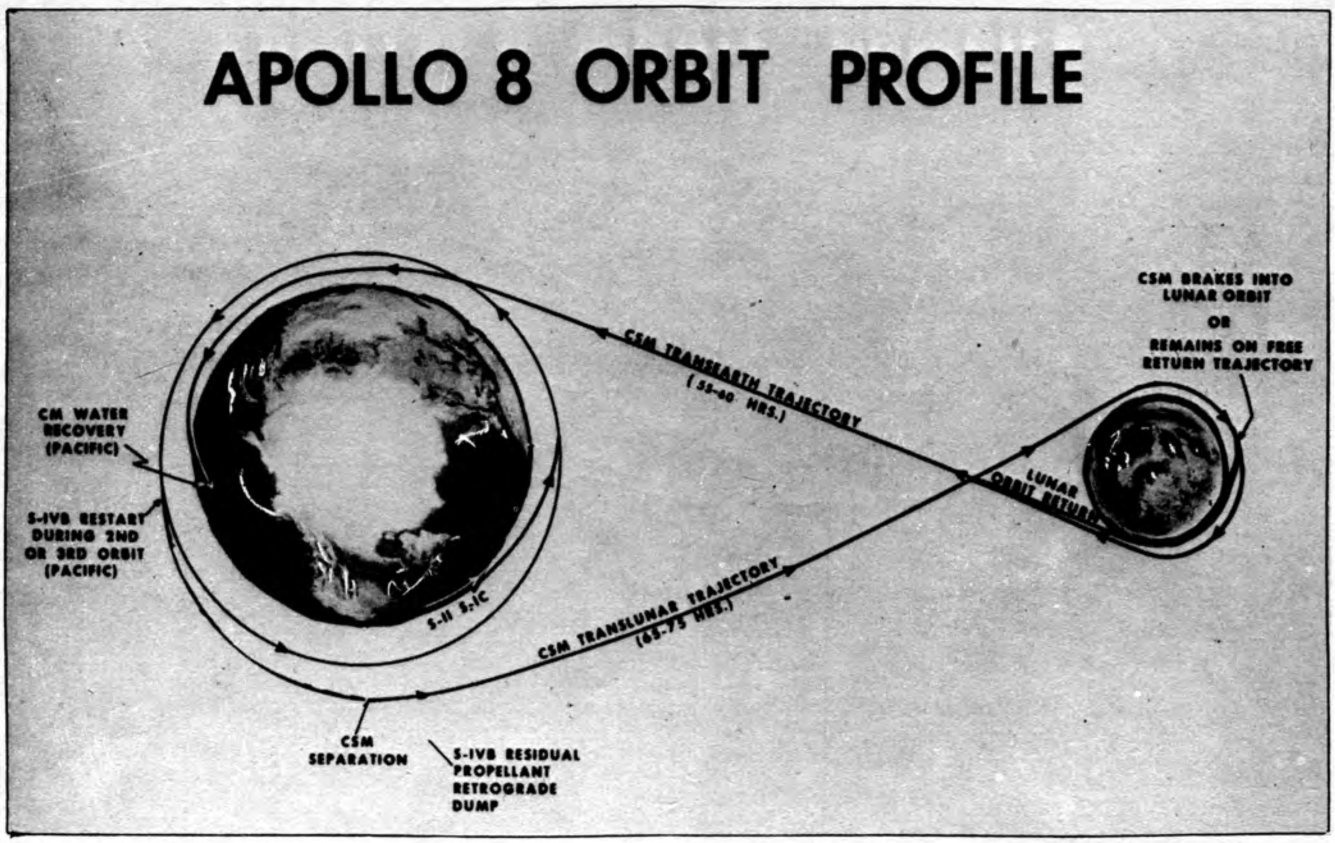
The Final Step – Apollo or Zond?

On the day following the launch of Zond 6 acting NASA Administrator Thomas Paine approved the final recommendation of George Mueller for a ten orbit mission about the Moon by Apollo 8. The decision had been long in coming. Since the first tentative proposal in early August, exhaustive plans and preparations were undertaken to ensure the feasibility of the mission and, uppermost, to ensure the safety of the crew. Together, Borman and Lovell had accumulated more time in space than the entire Soviet cosmonaut corps.

Obviously, there were great political advantages to be gained from a sucessful flight and equally disastrous prospects for the entire Apollo programme in the event of failure. But the harvest of technical data to be gained from such a flight would be invaluable to the lunar landing programme. Without the Lunar Module which would not be ready until March, 1969, an Earth orbital mission would not have significantly gone beyond the accomplishments of Apollo 7. Christopher Kraft had persuaded Frank Borman that if Apollo 8 was to go to the Moon a lunar orbit flight rather than a mere fly-by was essential [58].

The Saturn V itself actually made little difference in the decision to fly a lunar vice Earth orbital mission. After achieving Earth orbit the S-IVB third stage would be required to restart for the translunar injection burn. In the event it did not, the flight would shift to a contingency programme.

There were two main topics of concern expressed by those against the flight – the inability to return to Earth



APOLLO 8 ORBIT PROFILE. In this hastily prepared sketch issued by NASA on 29 November 1968 were encapsuled the exacting demands of the Apollo 8 mission – the first in which human beings would be isolated from Earth in lunar orbit.
National Aeronautics and Space Administration

immediately in the event of an emergency and the reliability of the SPS engine. It was true that if an emergency arose, Apollo 8 might not be able to return for several days, depending on the time and place of the emergency. But of all previous US manned space flights (17 to that date) only one, Gemini 8, had to abruptly end the mission with an emergency return to Earth. Even Gemini 8 could have remained aloft if necessary, but chose to land to play it safe. In retrospect, critics of the Apollo 8 decision point to the near-fatal accident of Apollo 13. If such an explosion had occurred on Apollo 8, they reason, the crew would have been doomed without a Lunar Module to serve as a 'lifeboat'. However, few of this group point out that if the accident had occurred soon after leaving the Moon, the Apollo 13 astronauts would probably never have survived either since the LM would have no longer been available. Apollo 8 would be far less dangerous than any flight after Apollo 9.

The Service Module propulsion system played a crucial role in the flight. If a malfunction occurred before entering lunar orbit, the spacecraft could return safely on a free-return trajectory. But once in orbit *only* the SPS engine could bring them home. Was this taking an unacceptable risk? The answer again is no. The engine was a superb combination of sophistication and simplicity. There were less than 100 moving parts which all had back-ups except the nozzle and the combustion chamber. The engine had been tested successfully over one thousand times on the ground and on three space flights, including eight firings by the Apollo 7 astronauts. Again on all Moon missions to follow, this propulsion system would be required to perform the same feats and the crew members' lives would depend upon it.

With a scheduled lift-off of Apollo 8 on 21 December, the world turned to watch the Soviet Union during the first two weeks of that month. If a manned Zond shot was to be attempted, launch would occur sometime between 1 and 12 December. Several US weekly news magazines hinted at just such a circumlunar mission [59, 60]. A report in *Spaceflight* in 1977 [61] gave 8 December as the probable target date. The launch never came. On 10 December A. A. Blagonravov, one of the leading Soviet space flight spokesmen, indicated that additional test flights would be required before sending cosmonauts around the Moon. How close did the Soviets actually come to launching a manned Zond in December? No one associated with the Soviet Union's space programme has ever said. One can only imagine Soviet space scientists secretly wishing Apollo 8 would be delayed at least one more month [62].

The rest is history. Apollo was not delayed and lift-off came at 0751 (EST) on 21 December. Almost three hours later after a "go" for translunar injection had been given, the S-IVB third stage was re-ignited, hurling men farther into space than they had ever gone before. Following an uneventful journey, Apollo 8 slipped into orbit around the Moon in the early morning hours of Christmas Eve, 1968. The race had been won. The world was captivated by the astronauts' descriptions of that ancient world and was humbled by the reading of Genesis in what until scarcely a decade ago has been considered God's domain.

Conclusion

Were the United States and the Soviet Union in a race to send men around the Moon in 1968? All the evidence points to that inescapable conclusion. Did the United States undertake a reckless adventure to "beat the Russians" at all costs? I think not. Apollo 8 was a daring mission, but so are

APOLLO 8 SPLASHDOWN. Astronauts Borman, Lovell and Anders await helicopter pick-up after splashing down in the Pacific Ocean near Hawaii on 27 December 1968. The spacemen orbited the Moon 10 times during their historic six-day journey away from the planet Earth.

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all great ventures. The risk to the safety of the crew was not significantly greater than in past missions and was less than in future ones. That is the way of exploration. This article has clearly shown that the decision to go into lunar orbit was begun before the flights of Zond 5 and Zond 6, contrary to popular belief. Although in August, 1968, there existed an implied aim by the USSR to conduct a manned circumlunar flight in the near future, these reports had been circulating for years with no firm basis and no demonstration of the hardware needed to accomplish such a feat.

Finally, even though the Zond circumlunar flights were vastly less ambitious and technically inferior, had the Soviets succeeded with a manned Zond mission around the Moon the subsequent Apollo 8-10 flights and even Apollo 11 would have paled in significance. Had Zond succeeded, the Soviets would have felt pressured to complete a lunar landing even after Apollo 11. Not ever having flown a manned Zond spacecraft made easier the Soviet decision in 1969-1970 to postpone their lunar landing programme indefinitely. However irrational, the Soviets today still claim that they were never engaged in a race to the Moon.

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SPACE SHUTTLE STATUS

The following summary reviews the status of the Space Shuttle as discussed in the presentation of John F. Yardley, NASA's Associate Administrator for Space Transportation Systems, before the House Subcommittee on Space Science and Applications.

A detailed Shuttle programme review has been completed to permit an accurate, updated assessment of cost, schedule and performance. The review showed that substantial progress has been made in the programme this year.

Highlights include the successful completion of the approach and landing test programme of Orbiter 101, 'Enterprise,' which has now been shipped to the Marshall Space Flight Center, Huntsville, Alabama, for mated ground vibration tests; recent mission duration test firings of the main engines at the rated power level; and the successful completion of the first phase of the three-engine configuration Main Propulsion Test Program.

With respect to overall Shuttle schedules, the review showed that all programme elements could be ready for a 28 September 1979, first manned orbital flight (FMOF) if all planned tests were successful and certain work adjustments were implemented. These adjustments involve the orbiter manoeuvring system (OMS) pod and the solid rocket motors (SRM), and could save about a month. September 1979 therefore has been set for the FMOF in an internal target working schedule. If unforeseen problems arise or the tests are not entirely successful, this schedule could be pushed back. However, NASA believes that there is a strong probability of flying the FMOF during FY 1979.

The programme review showed the only significant Shuttle problems to be with the main engine and the vehicle's weight.

While the engine development has been slower than desired, tests show that the engineis soundly designed. Substantial progress is being made with the Shuttle engine, and if testing continues to go well the engine could be certified in time for a September 1979 FMOF.

The weight problem does not present any constraint to early flight tests, but does present some problems for both the Galileo mission to Jupiter and certain Air Force missions. However, a weight-saving programme in the Orbiter and the external tank can satisfy all mission requirements until mid-1984. Performance augmentations being studied would enable the Shuttle to meet the identified requirements of all missions beyond that time.

Additional funding will be required to support the revised FMOF schedule and allow the most expeditious completion of the Shuttle's design, development test and evaluation programme. These funding requirements are not due to any single programme element, but are due to several items, including the main engines, solid rocket boosters, external tank and thermal protection system. Generally, more work has been found necessary than was originally estimated.

Shuttle development funding required in FY 1979 and FY 1980 exceeds previous plans. Our current estimate of the total Shuttle development costs is 8-9 per cent higher than the early estimate of $5.2 billion (1971 dollars).

The funding situation has been discussed with OMB and will be considered in the process of formulating the FY 1980 NASA budget. NASA is reviewing, together with the Department of Defense, the potential impact if additional Shuttle development funds are not available in FY 1979.

Our preliminary assessments show that the first manned orbital flight would be delayed an additional six to nine months over the above-estimated September date and that delivery of production orbiters would be delayed up to one year.

VENUS UNVEILED ?

Staff of NASA

As this issue appears two American spacecraft are making their final approach to the planet Venus. Pioneer Venus 1 launched on 20 May is expected to swing into orbit about 4 December. The "multiprobe" Pioneer Venus 2 launched on 8 August will arrive about five days later having previously separated probes for entry into the atmosphere. What will they find?

The Target

Venus is the planet most similar to Earth in size, mass and distance from the Sun. But its surface is much hotter, its atmosphere much denser, and its rotation much slower than that of Earth.

The diameter of Venus is 12,100 km (7519 miles), compared with Earth's 12,745 km (7920 miles). The mass of Venus is 0.81 times that of the Earth. The mean density is 5.26 grams per cubic cm compared with Earth's 5.5 grams per cubic cm.

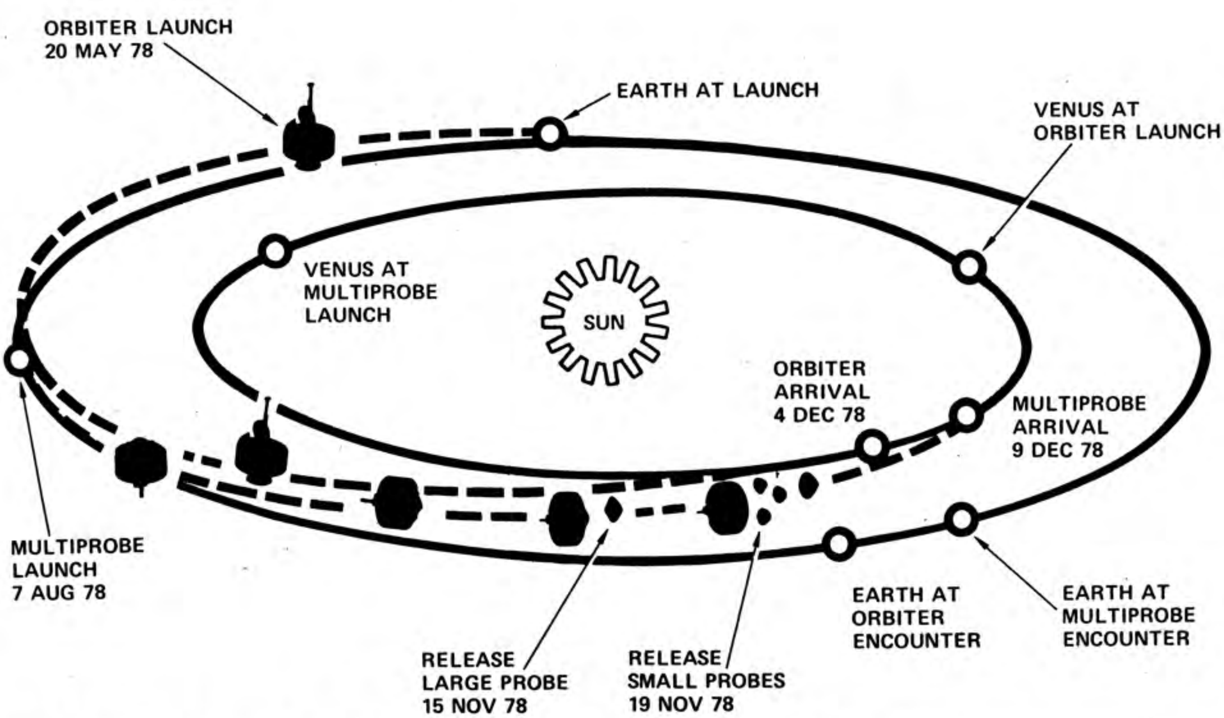
Because Venus is closer to the Sun, it receives about twice as much energy as Earth. However, it is more reflective than Earth because of its cloudy atmosphere. As a result of these two competing factors, Venus absorbs about the same amount of solar energy as Earth. Thus Venus would be expected to have a similar temperature. In fact, the surface of Venus is very hot, about 480 deg C (900 deg F).

Contemporary theory for the high temperature of Venus assumes that the atmosphere allows the passage of the incoming solar radiation to the lower atmosphere and the surface. The atmosphere restricts the passage of heat radiation from the surface and the lower atmosphere back into space. The heat is trapped. Earth has a modest greenhouse effect that raises its surface temperature by about 35 deg C (95 deg F), but in some parts of the infrared spectrum heat can escape by direct radiation from the Earth's surface to space. Because of its density, composition and clouds, the Venus atmosphere is very thick, and because it is mostly carbon dioxide, it is essentially opaque to outgoing heat radiation at all important wavelengths.

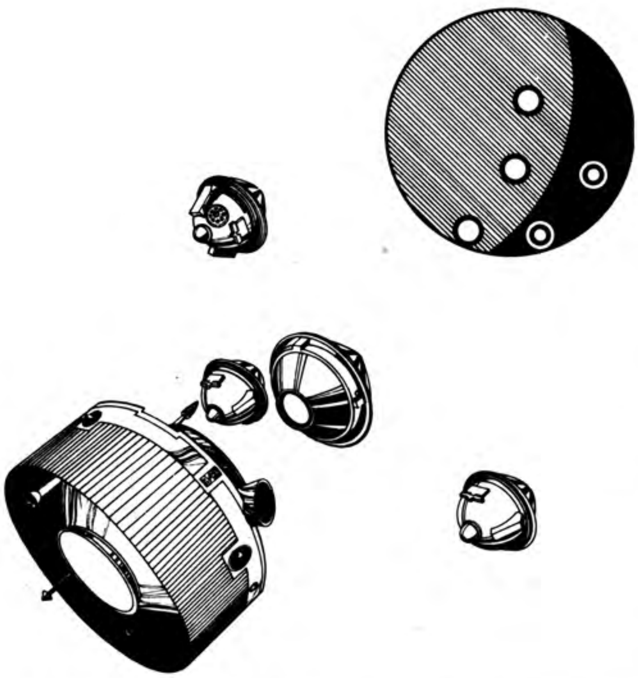
One of the most puzzling aspects of Venus is its lack of water. If Venus is as dry as it seems, where did the oceans of Venus go, if any ever existed? One speculation is that the water rose into the upper atmosphere and was dissociated by solar ultraviolet radiation into hydrogen and oxygen. The hydrogen escaped into space from the top of the Venus atmosphere, and the heavier oxygen diffused down to the oxidized crust. Detailed analysis shows that it might not be practical for Venus to have lost an ocean of water by such a route. Perhaps Venus formed close enough to the Sun so that the temperature prevented water from being incorporated into the solid material that formed the planet. If so, Venus would never have had enough water within its rocks to form early deep oceans like those of Earth. Direct measurements of gases within the Venus atmosphere may point toward one or two alternatives: Either that water was not incorporated into Venus as much as on Earth, or that water outgassed and was subsequently lost.

Orbit and Rotation

The rotation of Venus is very slow and in a retrograde direction, that is, opposite to the direction of the planet's



DOUBLE MISSION TO VENUS. The main purpose of Pioneer Venus 1 (actually launched 8 August) is to swing into orbit around Venus to study the planet for at least 243 Earth days (one Venerian day). The Pioneer Venus 2, which carries the probes, will penetrate the acid-filled clouds of Venus, transmitting back information about the atmosphere. The dual mission was described in *Spaceflight*, December 1977, pp. 431-434.



THE PÈNETRATORS. When the conical probes from Pioneer Venus 2 separate to make their data-gathering pass through the Venerian atmosphere, they will penetrate widely separated areas on both the light and dark side of Venus to maximise the mission's results. If Venus were Earth, the northerly probe would land on the tip of Norway, the large probe would impact in South America's Amazon Valley, while the remaining two would come to rest in Madagascar on the south east coast of Africa and at Montevideo, Uruguay. The cylindrical spacecraft also becomes a probe, but quickly burns up.

NASA

revolution about the Sun and to the rotation of most other planets. Venus turns on its axis once in 243.1 Earth days.

The orbits of Earth and Venus are tilted to each other about 3.5 degrees. Venus' axis is tilted about 6 deg from perpendicular to the plane of the planet's orbit. This compares with Earth's axial tilt of 23.5 deg which produces our seasons. Thus, seasonal effects on Venus are small.

Some scientists believe that Venus' period of rotation is tied to the revolution of the Earth and Venus around the Sun. Venus presents the same hemisphere toward Earth at each closest approach; that is, each time the planet passes between Sun and Earth. If the rotation of Venus is locked to the close approaches of Earth and Venus, then the internal distribution of mass within Venus should be slightly asymmetric.

Why does Venus rotate so slowly when most other planets rotate in periods of hours rather than months? One speculation is that a large body hit Venus and stopped its rotation. This large body might have been captured as a satellite into a retrograde orbit and later impacted with Venus to stop its normal rotation and rotate it slowly in an opposite direction.

It could be that Venus was formed from large fragments, and as a result of the combined impacts of these fragments never had much rotation. According to another suggestion, solar tidal effects in Venus' dense atmosphere may have slowed rotation and then "turned the planet over," accounting for its backward rotation.

Radar astronomers have mapped an area on the Earth-facing side of the planet as large as Asia and have found what appears to be a rugged surface. According to the radar results, there are huge shallow craters as well as an enormous volcano which may be as large in area, though not as high, as *Olympus Mons* on Mars. Radar astronomers also detected what appears to be an enormous canyon. This chasm is 1400 km (870 miles) long, 150 km (95 miles) wide, and several kilometres deep.

Planetary Interior and Absence of Magnetic Field

Unlike the Earth, Venus has no significant magnetic field. The generation of Earth's field is attributed to a self-sustaining dynamo in the fluid core of the planet. Convection currents in the core give rise to electric currents that produces the external magnetic field. This theory, which also seems to apply to Jupiter, predicts that slow-spinning planets like Venus should not have magnetic fields.

Venus is a planet whose shape could be very close to a sphere according to radar measurements. They show its equator to be almost a perfect circle. Because the poles do not rotate into view as do points on the equator, circularity around the poles cannot be measured. The lack of irregularities in shape, and of a satellite makes it difficult to determine the internal density distribution of the planet. Most models of the interior are based on its similarity to Earth, consisting of a liquid core, a solid mantle and a solid crust. But the true nature of the interior of the planet is very much in doubt because scientists do not know Venus' thermal structure or the nature of the materials which make up its mass.

Atmosphere of Venus

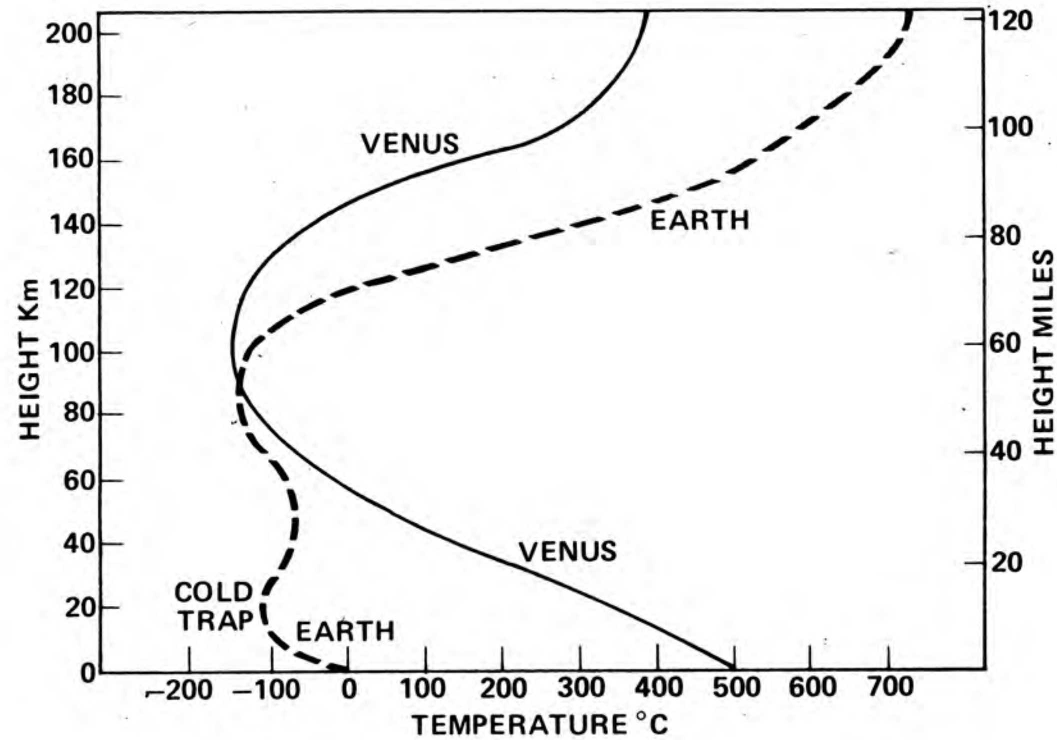
Carbon dioxide is the dominant gas in the Venerian atmosphere. There are also traces of water, carbon monoxide, hydrochloric acid and hydrogen fluoride. Free oxygen has never been found.

The clouds which obscure the surface of Venus consist of thick hazes of droplets believed to be made of sulphuric acid. Venus' clouds are pale yellow and very reflective, returning into space some 75 per cent of the sunlight falling on them. Space probe measurements have shown that there are distinct cloud layers much higher than terrestrial clouds. Photographs taken in ultraviolet light reveal a four-day rotation of the markings in these clouds. This rotation is like that of the planet, in a retrograde direction. Unusual dynamics of the atmosphere are required to account for this high-speed cloud motion.

The generally accepted figure for atmospheric carbon dioxide on Venus is 97 per cent. However, measurements made by early Soviet Venera spacecraft differ from radio occulation measurements suggesting the presence of about 70 per cent carbon dioxide in the Venerian atmosphere. And, if there is much argon in the atmosphere, the amount of carbon dioxide could be as low as 25 per cent.

Adding to the uncertainty is the fact that the percentages determined by the Veneras were obtained by sampling the atmosphere in regions where there are sulphuric acid droplets. The presence of acid may have contaminated these measurements. It is therefore possible to argue that the carbon dioxide is considerably less than 97 per cent, with the remainder being made up by some combination of nitrogen and argon.

The amount of carbon dioxide is important because it plays a major role in the interpretation of the microwave spectrum of the planet. If the atmosphere is 97 per cent carbon dioxide, the microwave observations permit the presence of as much as 0.1 per cent water below the clouds. Some instruments on the most recent Veneras 9 and 10 indicated that water vapour consituted about 1.0 per cent of the atmosphere below the main clouds. At the cloud tops



Venus – Earth temperature profiles.
NASA

it is only 0.0001 per cent, however. But, if there is another gas in the atmosphere of Venus that is not a good microwave absorber, the planet's atmosphere might contain more water than is now believed.

Carbon dioxide is also important to theories about the evolution of the atmosphere of Venus, and to the radiative properties of the present atmosphere and its dynamic characteristics.

The atmospheres of both Venus and Earth are assumed to have originated from gases that were released from the interiors of the planets which were hot when the planets first formed. In the case of Earth, most of the outgassing may have occurred soon after formation, from the heat of formation. Venus may never have had much water to outgas in the first place if it was formed from parts of the solar nebula that were poor in water. Or it may be that Venus formed with as much water as the Earth, but this water has now been lost.

The Earth holds its water in its oceans because it is much cooler than Venus and there is a "lid" on its atmosphere. This lid is the very cold tropopause where the temperature rises with altitude. This prevents heated water vapour from rising by convection to cooler heights where it could be dissociated by solar ultraviolet radiation. But if Earth were moved to the same distance from the Sun as Venus, conditions could change drastically. The additional solar energy would be sufficient to evaporate all of Earth's oceans.

If Venus had been formed from the same mix of materials as Earth and then outgassed its volatiles, we would expect it to have an atmosphere about 350 times as massive as Earth's. Carbon dioxide would account for a surface pressure of about 100 atmospheres, and water vapour would account for about 150 atmospheres. On Earth most of the 100 atmospheres of carbon dioxide is tied up in carbonate rocks which are chemically stable at terrestrial temperatures, but unstable at Venus temperatures. Earth's oceans, if vapourized, would result in at atmospheric pressure of about 250 atmospheres. Venus does indeed have nearly 100 atmospheres of carbon dioxide, but the water is apparently absent. There are no oceans, and the atmospheric water vapour is a minor constituent. One of the major questions to be answered by Pioneer Venus is just how much water vapour is present. Water vapour would be broken down by solar ultraviolet radiation into oxygen and hydrogen. The hydrogen would escape into space leaving the oxygen behind. Effectively the oceans would be leaking into space.

This could have happened to Venus. If the primitive atmosphere of Venus consisted mostly of steam (because the planet is closer to the Sun than Earth), the resulting convective atmosphere could not have had a barrier to convection. The water vapour would have dissociated into hydrogen and oxygen. Calculations suggest that within about 30 million years perhaps 90 per cent of the water could have been lost to the planet, but all could not be lost in this way.

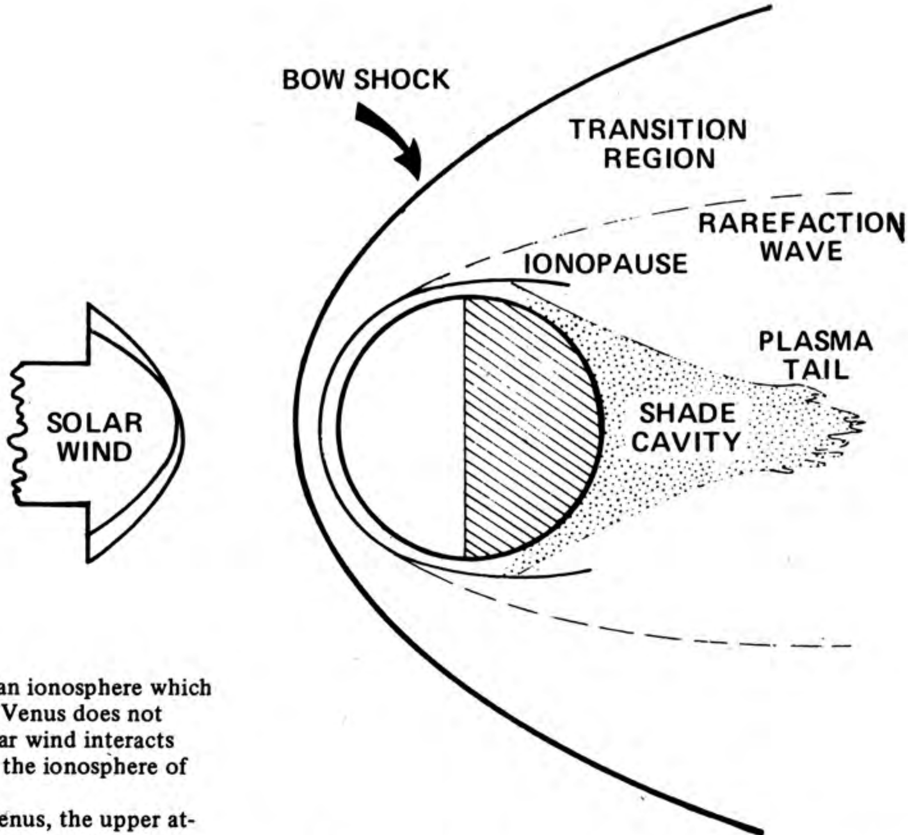
Furthermore, there is no easy way to explain what happened to the leftover oxygen other than that it reacted with the surface rocks. Yet without running water to continually expose fresh rocks for oxidation, the process might be insufficient to remove all the oxygen. Continental drift might be a possible mechanism to expose fresh rocks. There is a question, too, of what happens to the oxygen now released in the upper atmosphere by photodissociation of carbon dioxide to produce the carbon monoxide observed spectroscopically. The incorporation of oxygen with sulphur to form the sulphuric acid droplets does not seem to account for all the missing oxygen.

On Venus, because of the high surface temperatures, reactions between rocks, minerals and the atmosphere are expected to be much faster than on Earth. However, on Earth the action of running water constantly exposes new rocks to the action of the atmosphere and aids oxidation and other reactions between the rocks and the atmosphere. This is not happening on Venus. If fresh rocks are not being exposed by some other mechanism, the atmosphere of Venus may not have achieved equilibrium with surface materials.

The Venus atmosphere can be divided into three distinct regions: a region above the visible cloud tops which includes the ionosphere and the exosphere; a region of clouds; and a region from the base of the clouds to the surface.

Solar wind – Venus interactions.

NASA



Upper Atmosphere

The upper atmosphere of Venus has an ionosphere which is different from that of Earth. Because Venus does not have a significant magnetic field, the solar wind interacts directly with the upper atmosphere and the ionosphere of the planet.

Among the atmospheric regions of Venus, the upper atmosphere above the cloud tops is best understood. It has been investigated from Earth and from flyby and orbiting spacecraft. Above 150 km (90 miles) it is more rarefied than the atmosphere of Earth at the same height. Like Earth's atmosphere, it is ionized by incoming solar radiation to produce positively-charged ions and free electrons of an ionosphere, which is thinner and closer to the surface of the planet than Earth's ionosphere. Like Earth's ionosphere, the ionosphere of Venus has layers at which the number of electrons per cubic centimetre (electron density) peaks. In Earth's ionospheric layers, the peak electron density is about 100,000 to 1,000,000 electrons per cubic centimetre, and occurs at an altitude of about 250 to 300 km (150 to 180 miles). The major ion is singly-charged carbon dioxide.

Mariner 10 found two clearly defined layers in the nighttime ionosphere: a main layer at 142 km (87 miles) altitude and a lesser layer at 124 km (76 miles). The peak intensity of the latter was about 78 per cent of the higher layer. On the dayside there was one main layer at 142 km (87 miles) and several minor layers, including one at 128 km (78 miles) and another at about 180 km (110 miles). The Venera 9 and 10 orbiters obtained similar results, but single layers seem to be the most common.

From a practical standpoint, Venus has no intrinsic magnetic field. The field of Venus is less than 1/10,000 of Earth's field. There is a region of rarefaction (lessened density) of the solar wind flow at Venus, and the characteristics of the plasma there indicate that Venus absorbs part of the flux of the solar wind. On the dayside of Venus, there is a sharp boundary to the ionosphere at 350 to 500 km (210 to 305 miles). This is believed to be caused by the interaction of the solar wind with Venus' atmosphere. On the night side of the planet, the ionosphere extends high into space and probably into a plasma tail stretching away from the Sun.

Temperatures have been measured in regions above the visible cloud layers by radio occultation. The temperature of the exosphere (region where particles escape the planet) was derived from density variation with altitude found by the ultraviolet experiments of spacecraft. From observations of the ultraviolet radiation from hydrogen and helium atoms, it is calculated that the temperature of the exosphere of Venus when Mariner 10 flew past the planet was about 127 deg C (260 deg F). At such a temperature, the thermal escape of helium gas would be negligible. Accordingly it is thought that if helium outgassed from the rocks of Venus as it did on Earth the gas might have accumulated in the upper atmosphere of Venus. A corona of hydrogen begins at about 800 km (480 miles) and contains up to 10,000 atoms per cubic centimetre.

Haze Layers

At least two tenuous layers of haze can be seen in high resolution pictures of the limb (edge of the disc) of Venus. They extend from equatorial regions to higher latitudes. They may be associated with temperature inversions in the high atmosphere, and may result from process similar to those in Earth's atmosphere which produce layers of aerosols in the stratosphere. Aerosols are solid or liquid particles suspended in an atmosphere. The stratified layers of haze are in the region 80 to 90 km (50 to 56 miles) above the surface of Venus where the atmospheric pressure is between 50 and 0.5 millibars. (Pressure at Earth's surface is 1000 millibars). These haze layers are extremely tenuous. At the topmost haze layer, if the atmosphere is mainly carbon dioxide, the temperature should be -75 deg C. However, temperatures determined from occultations differ appreciably above 60 km (37 miles), suggesting temperature inversions that separate the haze layers from the topmost convective cloud deck as well as the upper from the lower haze layers. In the region above 50 km (30 miles), the daytime atmosphere is about 15 deg C (59 deg F) warmer than the temperature at night.

The Cloud Layers

Below the upper atmosphere is the 18 km (11 miles)-thick region containing the clouds of Venus visible from

Earth. While the clouds of Venus look extremely opaque, they are in fact very tenuous. Veneras 9 and 10 determined that visibility within the clouds is between 1 and 3 km (0.6 to 1.8 miles). They are more like thin hazes than terrestrial clouds. The particles making up the clouds of Venus are spherical and about one to two microns in diameter. These droplets apparently consist of sulphuric acid, with concentrations varying from 50 to 500 per cubic centimetre.

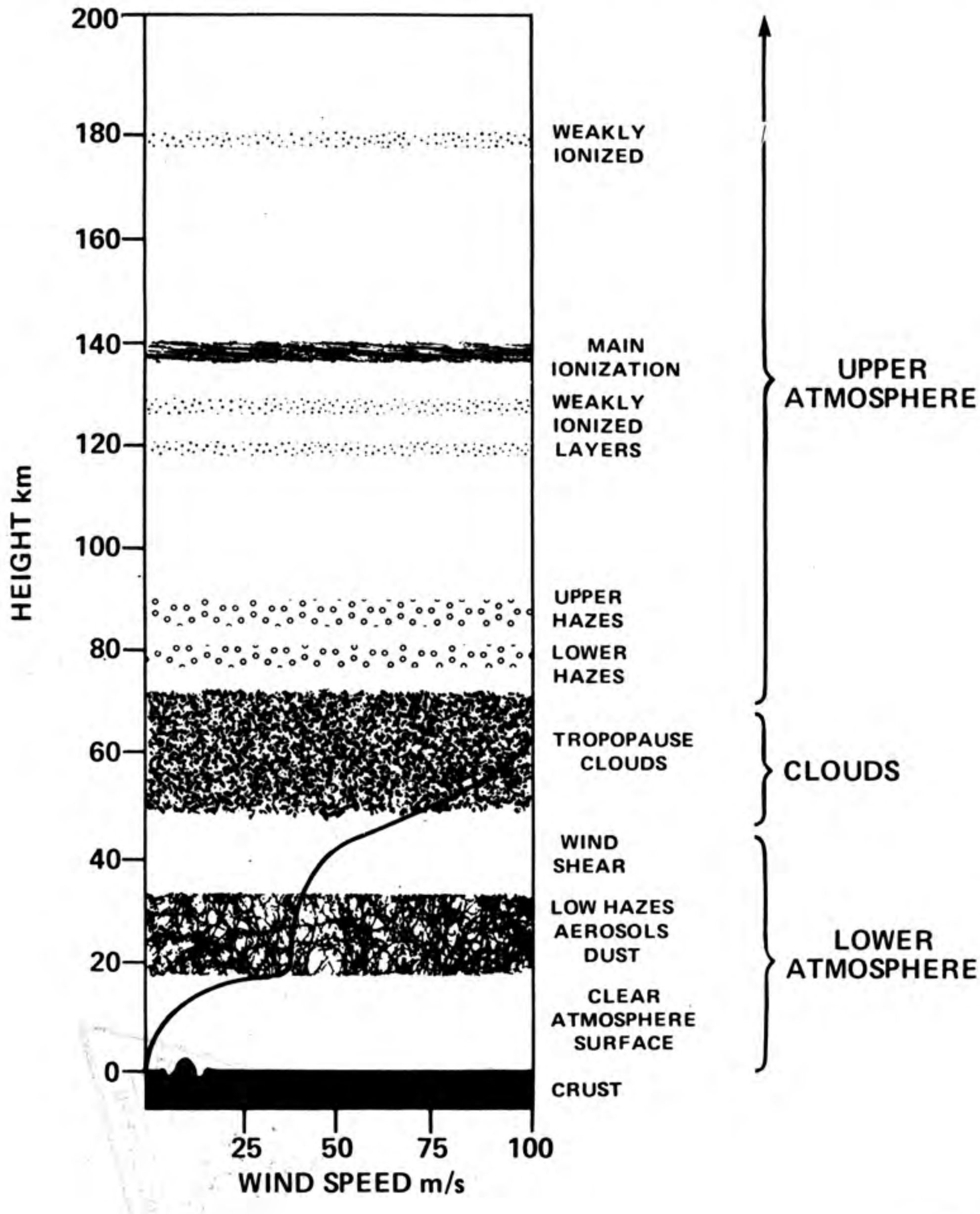
The presence of sulphuric acid clouds explain the extreme dryness of the Venus upper atmosphere. Nearly all the water has chemically bound up in the sulphuric acid droplets. The density of Venus' atmosphere at this level is about one-tenth the density of Earth's atmosphere at sea level. Sulphuric acid clouds remain as clouds over a wide range of temperature than water clouds, although high temperatures cause some of the water to evaporate from the droplets. There is evidence of the presence of fluorine in the Venus atmosphere. This element probably combines with water into the extremely stable and corrosive fluorosulphuric acid. But none of these acids can account for the absorption of ultraviolet radiation by the clouds. There must be an unknown ultraviolet absorber in the clouds which gives rise to the dark markings seen in ultraviolet pictures of Venus.

One speculation is that the dark regions seen in ultraviolet light are oxygen-depleted regions where a significant amount of ultraviolet-absorbing sulphur is being produced. There appears to be a whole series of compounds of sulphur, oxygen and halogens that enter into the chemistry of the atmosphere of Venus.

The Pioneer Venus measurements of the constituents of the atmosphere of Venus with a mass spectrometer and gas chromatograph should contribute greatly to our understanding of these chemical processes that are responsible for the Venerian clouds and their markings.

The dark markings of the clouds, seen in ultraviolet light, have characteristic forms that have been studied from Earth. There are horizontal Y-shaped features which sometimes have a tail. There are features that look like a reversed letter C. The features in the form of a reverse letter C appear more often on the evening terminator than on the morning terminator. Other features are like a reversed C with a bisecting bar. Sometimes there are two parallel equatorial bands. The patterns are also almost always symmetrical about the equator of Venus. The arms of these features are always open in the direction of their retrograde motion which varies between 180 and 470 km/hr (112 to 265 mph).

In the upper atmosphere the effects of solar heating are



Venus atmosphere.

NASA

significant, and the C-bar, C- and Y-shaped features are all associated with the sub-solar point, which is the point where the Sun shines down on the Venus atmosphere from directly overhead. However, the features move around the planet and are not fixed with respect to the sub-solar point.

A big question about Venus' atmosphere is whether the apparent motions of the ultraviolet markings are a result of actual movement or merely a wave motion. The evidence today points to an actual movement of mass; i.e., winds. But there is some evidence of wave motions, diurnal tides and parallel equatorial belts.

The division between the high wind velocities of the stratosphere, and the near calm of the dense surface atmosphere seems to come at about the 56 km (36 miles) level. The big change in wind velocity thus appears to take place at the bottom of the clouds where there must be a shear zone. Thus, the cloud bottoms are expected to be extremely ragged.

The Soviet probes measured the amount of solar radiation down to the surface. Above 50 km (31 miles), scattering appears to be by the cloud particles. Below about 25 km (15 miles), the scattering is Rayleigh scattering; i.e., by much smaller air molecules. At the surface, with the Sun's position about 30 degrees from overhead, the integrated flux was measured as being about equal to that on an overcast day on the Earth at sea level in mid-latitudes.

The high velocity winds in the Venus atmosphere might arise because the planet has such a massive and deep atmosphere. Large-scale eddies containing a lot of energy could transport momentum from low to high altitudes with a high amplification. The ion wind speeds in the dense lower atmosphere produced by the heat from the Sun and the rotation of the planet are amplified into the thin upper atmosphere.

Lower Atmosphere

The penetration of Veneras 9 and 10 into the lower atmosphere produced new information about this region. At about 50 km (30 miles) altitude, the wind velocity appears to be about 130 km/hr (80 mph). At the landing site of Venera 9, the local wind velocity varied from 1.2 to 2.5 km/hr (0.9 to 1.4 mph); at the Venera 10 site, it varied from 2.9 to 4.7 km/hr (1.8 to 9.2 mph). The two landers thus confirmed a low wind velocity close to the surface, as well as little dust content in the low atmosphere.

Unresolved Questions

There are still many unresolved questions about the atmosphere of Venus that need to be answered, such as:

- How does the Venus weather machine really work?
- It is really a greenhouse effect that makes Venus so hot compared with the Earth? Or is there a dynamic cause?
- Did Venus once have a more moderate surface temperature?
- What causes the dark markings in the Venus clouds?
- What are the constituents of the Venus atmosphere?

Thermal emission from the upper atmosphere differs very little between night and day and between low and high latitude. This indicates a dynamic activity within the atmosphere, and suggests that heat in substantial amounts is being transferred around the planet horizontally. There are dynamic activities at all levels because spacecraft have determined that the solar radiation penetrates through the clouds and, therefore, affects the atmosphere down to the surface. Direct solar heating is most important above 56 km (34 miles); dynamic effects below that.

Over the whole of the planet there is also the effect of the atmosphere at the equator rising as it is warmed by sunlight, and sinking near the Poles, as it cools.

The Surface of Venus

Radar has revealed large-scale features that suggest tectonics and impact moulding of Venus' topography. Details of the surface have been provided by the Soviet lander spacecraft.

The radar observations reveal a large-scale granular structure, suggestive of a rock-strewn desert. Large but shallow circular features, most likely craters, are found in equatorial regions. Some areas of high radar reflectively are interpreted as extensive lava flows and mountainous areas. A major chasm stretches 1400 km (870 miles) north and south across the equator.

At five degrees south latitude and 320 degrees longitude is the high mountain Beta with a cratered top like the large Martian volcanoes. There are also accurate ridges. One is at least 800 km (480 miles) long. There are mountainous areas which may be volcanic or a result of crustal plate movements.

Photographs from one Soviet lander spacecraft confirm a dry rocky surface that has been fractured and moved about by unknown processes. The second lander produced a picture of rocks with rounded edges and pitted surfaces. The forms of these rocks may be explained by volcanic activities having taken place on the surface.

The existence of craters on Venus suggests that its surface has not been subjected to the major tectonic changes experienced on Earth, but that it has probably evolved somewhat along the same lines as Mars. Some old cratered terrain is preserved while other parts have been modified by tectonics and volcanism. Venus might, indeed, have evolved to a stage between that of Mars and that of the Earth.

Venera 9 landed at 33 deg north latitude. Its picture shows heaps of rocks, mostly about 30 cm (12 in.) or more in size, and with rather sharp edges. The formation of these rocks is believed to be associated with tectonic processes. The lander is believed to be on the side of a hill in which there is some downward movement of the rocks. The sharp edges and lack of rounding of the rocks at this site suggest that they were formed from breakage of hard, layered rocks, possibly a lava flow.

Venera 10 landed at 15 deg north latitude, in an area with a much smoother surface. This is believed to be a plateau or plain of greater relative age than the site of Venera 9. There are some rocky elevations which are covered with a relatively dark, fine-grained soil. This implies that the rocks have been weathered, possibly by chemical action with the atmosphere. It is unlikely that the gentle winds at the surface could have been responsible for the weathering. Generally at this site the material of the Venerian soil is dark, but there are outcrops of lighter coloured rock penetrating the soil. Some of the dark soil fills depressions of the outcrops. This surface is interpreted as being much older and more weathered than the surface seen at the Venera 9 site. The weathering process may be a chemical interaction between the hot rocks and the atmosphere, possibly by mineral acids and water vapour.

Measurements made by the spacecraft indicate that the surface rocks have a density between 2.7 and 2.9 grams per cubic centimetre, which is typical of terrestrial basaltic rocks.

Surface temperatures appear to be high enough to make portions of the surface glow a dull red. They are high enough to melt zinc, but not most common rocks. The Venus rocks at the two landing sites are about as radioactive as terrestrial lavas and granites. This suggests that Venus, like Earth, has differentiated by heating to form a dense

core and a lighter crust.

Though it has dramatic major features, the surface is smoother than that of Earth and Mars. Radar-measured minimum to maximum height differences are 10 km (6 miles) – the height of Mt. Everest. This compares with 20 km (12.4 miles) on the Earth, from the bottom of the Mariannas Trench to the top of Everest. It compares with 30 km (18.6 miles) on Mars, from the floor of the *Hellas* basin to the peak of *Olympus Mons.* Craters on Venus seem to be shallower than on the other worlds of the inner Solar System.

On the Moon and Mercury, and to a somewhat lesser extent on Mars, the ratio of craters diameter to depth is about 10 to 1. On Venus, according to the radar surveys, the ratio is more like 100 to 1. The craters on Venus seem to be extremely shallow; the reason is not known. It could result from plastic deformation of the hot surface or from some weathering process.

Major Questions About Venus

- *Apart from carbon dioxide, of what does the lower atmosphere consist, and how are its constituents distributed?*

Venus probably has less than seven per cent of gases other than carbon dioxide in its lower atmosphere. Most likely candidates for other major gases are argon and nitrogen. There are no measurements of lower atmosphere gases other than the Soviet measurements of carbon dioxide and water vapour.

- *Of what materials are Venus' clouds made?*

The visible clouds probably consist of sulphuric acid droplets, perhaps formed by sulphur compounds from the surface.

- *What other cloud layers are there?*

Some kinds of cloud particles absorb solar ultraviolet radiation. This is needed to explain the ultraviolet photographs which show dark regions. These different kinds of cloud particles could be metal halides or sulphur.

- *What can the lowermost atmosphere tell us about the planet's surface and interior?*

Surface constituents (possibly hydrogen fluoride and mercury and sulphur compounds) may be detectable in the bottom 20 km (12 miles) of the hot, dense atmosphere.

- *How does temperature, pressure and density vary globally about the planet?*

- *Why is Venus' lower atmosphere so hot?*

This is probably due to a runway greenhouse effect in which heat from the Sun is more easily absorbed than re-radiated.

- *What role do vapourization-condensation cycles play in the atmosphere, and how do these processes affect Venus' weather?*

- *What are the composition and temperature profiles of the upper atmosphere?*

- *How does temperature vary in space and time in the upper atmosphere?*

- *What are the roles of global circulation and local turbulence in stabilizing the upper atmosphere?*

- *What are the effects of the neutral particles on ionosphere compositions?*

- *How high does super rotation (four-day rotation) of the cloud tops extend?*

- *Since Venus has no magnetic field, the solar wind interacts directly with the upper atmosphere. What mechanisms does this create, and do they affect the lower atmosphere?*

- *Where did Venus' atmosphere come from and where is it going?*

The main sources of Venus' atmospheres probably are outgassing from the interior, gases from the original solar nebula and some solar wind particles.

- *Where is the water that may have once been on Venus?*

The obvious answers are that it either "leaked" to space because of high Venus heating, or it was never there. But numerous questions remain.

- *Why does Venus' atmosphere differ so much from that of its "twin" planet, Earth?*

- *Is all Venus terrain relatively low compared to Earth and Mars or does Venus' "invisible hemisphere" contain high mountains and deep canyons comparable to those on Earth and Mars?*

- *Is Venus as close to a perfect sphere as the equatorial measurements suggest?*

- *Does Venus' interior contain large concentrations of high density material.*

The locking of Venus' rotation to Earth's orbit suggests such mass concentrations.

- *What is the surface topography?*

- *What is the composition of the surface?*

MILESTONES / *continued from page 402*

When the eggs were about to hatch, they would be returned to Earth to permit study of all the pre-natal stages of development of a living creature in weightless conditions.

9 *Novosti* reports that Vladimir Kovalyonok and Alexander Ivanchenkov "will return to Earth towards the end of October" after spending 10 days unloading Progress 4 and refuelling Salyut 6's engines. With the unloading operation completed, "the cosmonauts will complete a number of technological, medical and biological experiments and then mothball the station and return to Earth."

9 ESA reports that the functioning of the scientific satellite GEOS 2 is being perturbed by a short-circuit between a series of solar cells and the spacecraft structure. The defect is affecting three of the seven scientific experiments: S-300, measurement of magnetic fields and waves, and S-302 and S-303, measurement of low-energy particles. The perturbations are observed for very short periods corresponding to the illumination phase of the damaged part of the solar array.

U.S. SPACE POLICY

The following Press Statement has been issued by the White House on the subject of U.S. national space policy. It contains the unclassified portions of a Presidential Directive issued after a year of interagency study.

The President directed under a Presidential Review Memorandum that the NSC Policy Review Committee (PRC) thoroughly review existing policy and formulate overall principles which should guide our space activities. The major concerns that prompted this review arose from growing interaction among our various space activities.

This review examined and the resultant Presidential Directive establishes:

- A government policy oversight system to review and revise space policy as needed;
- Ground rules for the balance and interaction among our space programmes to insure achievement of the interrelated national security, economic, political, and arms limitation goals of the U.S., and
- Modifications to existing policies, the appropriate extent of the overlapping technology, and product dissemination by the sectors.

This Presidential Directive establishes an NSC Policy Review Committee to provide a forum to all Federal agencies for their policy views, to advise on proposed changes to national space policy, to resolve issues referred to the Committee, and to provide for rapid referral of issues to the President for decision as necessary. This Committee will be chaired by the Director of the Office of Science and Technology Policy, Frank Press. Recognising that the civilian space programme is at the threshold of change, the President has asked the PRC to assess the needs and aspirations of the nation's civil space programme. The United States has built a broad national base in space and aeronautics. At issue is how best to capitalize on prior investments and set the needed direction and purpose for continued vitality in the future.

Under the Presidential Review Memorandum the emphasis was to resolve potential conflicts among the various space programme sectors and to recommend coherent space principles and national space policy. In focussing upon these issues, the Policy Review Committee concluded that our current direction set forth in the Space Act of 1958 is well founded and that the preponderence of existing problems was related to interractions and resultant stresses among the various space programmes. For this reason, the classified portion of the recently signed Presidential Directive concentrates on overlap questions. It does not deal in detail with the longterm objectives of our defence, commercial, and civil-programmes. Determining our civil space policy, outlined above, will be the next step.

As a result of this in-depth review, the President's Directive establishes national policies to guide the conduct of United States activities in and related to space programmes. The objectives are (1) to advance the interests of the United States through the exploration and use of space and (2) to co-operate with other nations in maintaining the freedom of space for all activities which enhance the security and welfare of mankind. The space principles set forth in this Directive are:

(a) The United States will pursue space activities to increase scientific knowledge, develop useful commercial and government applications of space technology, and maintain United States leadership in space technology.

(b) The United States is committed to the principles of the exploration and use of outer space by all nations for peaceful purposes and for the benefit of all mankind.

(c) The United States is committed to the exploration and use of outer space in support of its national well-being.

(d) The United States rejects any claims to sovereignity over outer space or over celestial bodies, or any portion thereof, and rejects any limitations on the fundamental right to acquire data from space.

(e) The United States holds that the space systems of any nation are national property and have the right of passage through and operations in space without interference. Purposeful interference with space systems shall be viewed as an infringement upon sovereign rights.

(f) The United States will pursue activities in space in support of its right of self-defence and thereby strengthen national security, the deterrence of attack, and arms control agreements.

(g) The United States will conduct international co-operative space activities that are beneficial to the United States scientifically, politically, economically, and/or militarily.

(h) The United States will develop and operate on a global basis active and passive remote sensing operations in support of national objectives.

(i) The United States will maintain current responsibility and management relationships among the various space programmes, and, as such, close co-ordination and information exchange will be maintained among the space sectors to avoid unnecessary duplication and to allow maximum cross-utilization of all capabilities.

Our civil space programmes will be conducted to increase the body of scientific knowledge about the Earth and the Universe; to develop and operate civil applications of space technology; to maintain United States leadership in space science, applications, and technology; and to further United States domestic and foreign policy objectives within the following guidelines:

- The United States will encourage domestic commercial exploitation of space capabilities and systems for economic benefit and to promote the technological position of the United States; however, all United States Earth-oriented remote sensing satellites will require United States government authorisation and supervision or regulation.
- Advances in Earth imaging from space will be permitted under controls and when such needs are justified and assessed in relation to civil benefits, national security, and foreign policy. Controls, as appropriate, on other forms of remote Earth sensing will be established.
- Data and results from the civil space programmes will be provided the widest practical dissemination to im-

prove the condition of human beings on Earth and to provide improved space services for the United States and other nations of the world.

- The United States will develop, manage, and operate a fully operational Space Transportation System (STS) through NASA, in co-operation with the Department of Defence. The STS will service all authorised space users – domestic and foreign, commercial and governmental – and will provide launch priority and necessary security to national security missions while recognising the essentially open character of the civil space programme.

Our national security related space programmes will conduct those activities in space which are necessary to our support of such functions as command and control, communications, navigation, environmental monitoring, warning and surveillance, and space defence as well as to support the formulation and execution of national policies; and to support the planning for and conduct of military operations. These programmes will be conducted within the following guidelines:

(1) Security, including dissemination of data, shall be conducted in accordance with Executive Orders and applicable directives for protection of national security information. Space-related products and technology shall be afforded lower or no classification where possible to permit wider use of our total national space capability.

(2) The Secretary of Defence will establish a programme for identifying and integrating, as appropriate, civil and commercial resources into military operations during national emergencies declared by the President.

(3) Survivability of space systems will be pursued commensurate with the planned need in crisis and war and the availability of other assets to perform the mission. Identified deficiencies will be eliminated and an aggressive, long-term programme will be applied to provide more assured survivability through evolutionary changes to space systems.

(4) The United States finds itself under increasing pressure to field an anti-satellite capability of its own in response to Soviet activities in this area. By exercising mutual restraint, the United States and the Soviet Union have an opportunity at this early juncture to stop an unhealthy arms competition in space before the competition develops a momentum of its own. The two countries have commenced bilateral discussions on limiting certain activities directed against space objects, which we anticipate will be consistent with the overall U.S. goal of maintaining any nation's right of passage through and operations in space without interference.

(5) While the United States seeks verifiable, comprehensive limits on anti-satellite capabilities and use, in the absence of such an agreement, the United States will vigorously pursue development of its own capabilities. The U.S. space defence programme shall include an integrated attack warning, notification, verification, and contingency reaction capability which can effectively detect and react to threats to U.S. space systems.

ICEBREAKER STEERED VIA SPACE

The extent to which Russia is using artificial satellites in conjunction with shipping has been emphasised recently by the voyage of the nuclear-powered icebreaker *Sibir* from Murmansk to the Bering Strait.

The vessel used no fewer than four types of satellite to ensure a safe and comfortable journey for the crew whose mission was to find more economical routes for shipping in the Northern Seas.

Cosmos 1000 – a navigation satellite – provided the information used by the ship's computer to fix an exact position. Meteor weather satellites gave the crew pictures of cloud cover, snow conditions and sea ice to enable them to choose the best route.

Molniya communications satellites allowed the ship to maintain regular contact with headquarters and Ekran, the Soviet television satellite in orbit 22,300 miles above the equator, sent the crew entertainment from Moscow.

NASA ASTRONAUT CANDIDATES

Thirty-five new astronaut candidates who reported to NASA's Johnson Space Center, Houston, Texas, on 10 July 1978, have begun a two-year training and evaluation period. Formal training which started on 11 July included aircraft life support and ejection seat training for the T-38 aircraft, aircraft physiological training and T-38 aircraft systems and operations.

The astronaut candidates also went to Homestead Air Force Base in Florida for the standard Air Force water survival course given by USAF instructors.

In subsequent weeks, the candidates attended lectures on the history of space flight, technical assignment methods and procedures within the astronaut office, lessons on manned spacecraft engineering, Space Shuttle programme, aerodynamics, flight operations and the many disciplines associated with preparation for and operation of vehicles in space.

Instructors and lecturers for the series of lessons and briefings were astronauts, engineers, management and support contractors at JSC.

SCIENCE ON SALYUT 6

The scientific programme of Soyuz 29 cosmonauts Vladimir Kovalenok and Aleksander Ivanchenkov on board the Salyut 6 orbital laboratory was similar to that of the previous 'resident' crew Yuri Romanenko and Georgi Grechko, but the pacing of the cosmonauts workload was altered slightly after study of the reactions of Romanenko and Grechko to a prolonged orbital flight, writes Neville Kidger.

Kovalenok and Ivanchenkov during their long duration flight settled down to a 5 day week with Saturday and Sunday off. This allowed them more time for their personal needs and for catching up with paper work. They worked on a 9 to 5 basis, just like most office workers, but were willing to put in overtime, of course, and often did. In addition they were allowed an extra hour per day in bed, making a total of 9 hours per day of sleeping time. The length of time one needs to spend sleeping in space varies according to the individual. Some astronauts during the Skylab flights found that 8 hours per day was too much. Some thought it about right, while others felt that they needed a bit more time "in the sack" to regenerate their energy. These changes to the cosmonauts schedule were suggested by Romanenko and Grechko based upon their experiences.

Most of the cosmonauts' time was spent on observing the Earth, material processing, medical experiments and astronomical research. But there was quite a lot of work to do unloading the Progress transport spacecraft which delivered freight to Salyut and maintaining Salyut's systems. The

general household chores included preparing the station for visits by other crews including Polish and East German cosmonauts. The first of these visits, lasting a week took place in late June.

Whilst preparing Salyut 6 for their stay the cosmonauts worked to a more relaxed schedule than that of their predecessors, doing the minimum amount of 'de-mothballing' during the first days on the station, "working at their own discretion," according to their personal physician Dr. Robert Vasilyevich Dyakonov. Kovalenok and Ivanchenkov, the *'Photon'* crew, took less than the 7 days that Romanenko and Grechko, the *'Taymyr'* crew, took to adapt to the weightlessness environment, a factor aided by the experiences and recommendations of the *'Taymyr'* crewmen. They recommended that the *'Photon'* crew wear the 'Penguin' suits from the very first hours in the station. The cosmonauts retained a jocular mood and in one communications session Kovalenok mentioned cheerfully how easy it was to loose one's bearings in the station. The regular telecasts from Salyut helped to confirm their good state of health.

Yuri Romanenko, commander of the previous expedition to Salyut 6 and now in charge of one of the ground support groups, said early in the flight that the cosmonauts had already logged 'most interesting phenomena'.

During their second week in orbit the Salyut crewmen reported that "at present" the Sun could be observed without using a light filter; it neither rose nor set, but just rolled around on the horizon. Vesolod Aleksandrovich Ivanoc of the Space Research Institute said that in the unusual orbit – "a solar orbit" – the Sun was constantly visible and did not disappear over the horizon. The atmosphere was, so to speak, concealing the Sun's bright colour. It was in fact the indirect rays of the Sun which enabled one to make out special features in observations. The cosmonauts had described an unusual and interesting phenomenon, which still needed to be be checked and investigated. Whilst flying over the Pacific they reported observing "some very large underwater ridges"; changes in currents often occurred near ridges and such a formation on the ocean bed often influenced the whole life of the ocean. The phenomenon had only become visible because of the change in its illumination. During the flight the special position of the Sun would make it possible to discover new and unique phenomena.

According to Candidate of Technical Sciences, Victor Mikhaylovich Sviridov, of the State 'Priroda' (Nature) Center, the cosmonauts had sighted four submarine ridges near the Soloman Islands. There was a large area of plankton and a powerful counter-current, distinguishable by its contrasting colours; the cosmonauts had reported seeing them and agreed to photograph them. Sviridov spoke to the cosmonauts via radio whilst Salyut 6 flew over New Zealand.

Professor Aleksander Ivanovich Lazarev, of the Leningrad State Optical Institute, said that Salyut's new crew would be continuing observations made by their predecessors. One programme of observations of atmospheric optical phonomena had been delivered by Dzhanibekov and Makarov at Grechko's request; it had been left aboard the station and would be used by the new crew. The observations made by Romanenko and Grechko of the dark side of the Earth were of particular interest. The first emission layer was stratified into several independent layers; and, whereas the first emission layer was global, the second was limited to the equatorial zone within some 20 degrees north and south of the equator. "We have asked the crew to pay attention to observation of the vertical ray structure in the second emission layer," Lazarev said. These phenomena had first been observed by Vitali Sevastyanov from Salyut 4. The first Salyut 6 crew was for some reason unable to carry out these observations, and so the second crew had been asked to pay particular attention to them. Attention was also given to the movement of the silvery (noctilucent) clouds observed over the poles on the previous flight and the new crew would continue the observations, begun by Grechko aboard Salyut 4, of the points at which the planets rose and set on Earth's horizon. During the Soyuz 25 flight in October 1977 Kovalenok had drawn attention to certain optical phenomena which had not been previously observed: when mist appeared on an agitated sea surface the effect was like a magnifying lens. Analysis indicated that it was linked with the change in the atmosphere's transparency and clarity when mist formed, and with the worsening in visibility of the contacts on the sea surface from space; it was this that gave the impression of a magnifying effect.

The programme of photographing the Earth with the multispectral camera system MKF-6M was also continued. Earlier photographs had aided the economy greatly in taking inventories of crops and spotting pestilence in crops before this became visible on the ground. Photographs from space helped scientists to counter the Siberian silkworm, which is a major problem for Siberian trees in the same manner as Dutch elm disease was a major problem for trees in Europe. Chemical preparations had been used against the pest for some time but they are now being used more effectively after the photographs showed where the silkworm infestation was worst and where it was spreading.

In preparation for their mission Kovalenok and Ivanchenkov had trained in a Tu-134 aircraft flying at 9000m altitude being briefed by specialists from such diverse disciplines as geology, glaciology and oil prospecting. They explained to the cosmonauts what features to look for from Salyut. The cosmonauts had 15 specific assignments related to this programme. All of the cosmonauts selected for the Salyut 6 mission were trained in this way.

SPACELAB 1 MISSION SPECIALISTS

Astronauts Dr. Owen K. Garriott and Dr. Robert A. Parker have been selected by NASA to serve as Mission Specialists on the Spacelab 1 mission which is scheduled for the early 1980's.

This first flight of Spacelab is planned as a seven day flight and is primarily for the verification testing of the Spacelab systems and Spacelab and Orbiter interfaces. In addition, approximately 40 experiments will be on board.

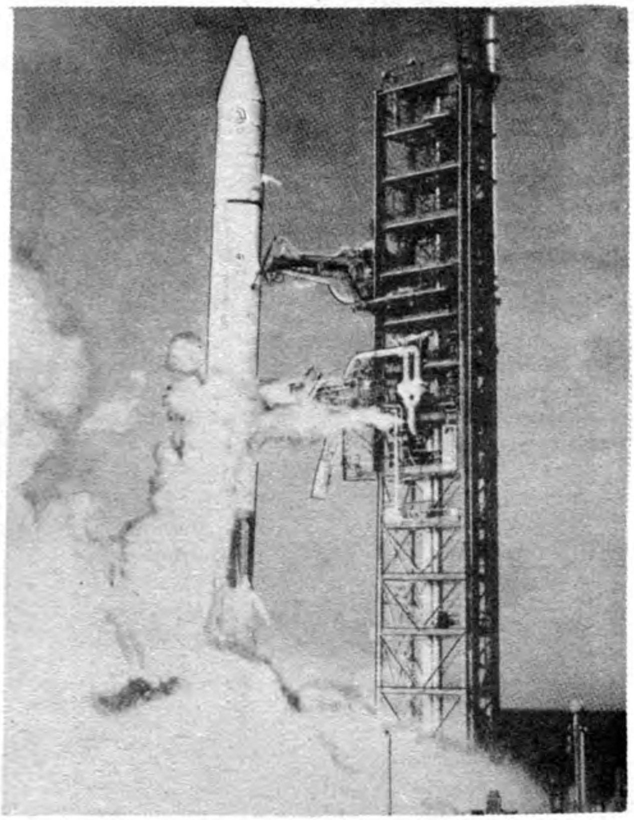
Garriott flew on the second manned Skylab mission of 56 days duration. Parker served as Mission Scientist and Spacecraft Communicator during Apollo and Skylab. For the past four years Parker has been involved in reviewing developments of Spacelab for the Astronaut Office.

Mission Specialists have overall responsibility for the coordination, with the Commander and Pilot, of Space Shuttle operations in the areas of crew activity planning, consumables usage and Space Transportation Systems/payload interaction.

Spacelab, developed and financed by 10 European nations under agreements concluded with the European Space Agency, will be carried in the cargo bay of the Shuttle Orbiter. The lab will supply investigators with a fully furnished laboratory adapted for the weightless environment of space and pressurized for working without spacesuits. In addition to the Commander, Pilot and two Mission Specialists, Spacelab 1 will include two Payload Specialists, one European and one U.S. citizen who have primary responsibility for operating the science instruments.

With six crewmen on board it will be possible to have two operational shifts of three crewmen each, consisting of a Mission Specialist, Commander/Pilot and Payload Specialist.

Continued on page 423]



DOMESTIC LONG-DISTANCE COMMUNICATIONS SATELLITE COMSTAR D-3 lifts off aboard Atlas Centaur 41 from Cape Canaveral on 29 June 1978. It was the third in a series of such satellites to be launched by NASA for COMSAT General Corporation. In geostationary orbit, the satellites are used primarily for domestic long-distance telephone service in the United States.

National Aeronautics and Space Administration

NEW SHUTTLE MATERIAL

Work is under way at Boeing Aerospace Company in an effort to prove that a newly developed composite material can dramatically reduce the weight of future space shuttles.

The material is made of a new high-temperature-resistant polymer, developed by NASA, reinforced with continuous graphite filaments. It is expected to reduce the weight of spacecraft parts by as much as 25 per cent.

The development work is being done by the material technology group of Boeing's Engineering Technologies organisation under a $326,000 contract from NASA's Langley Research Center.

Boeing has made a variety of structures from the new material, the largest of which is a section of a shuttle aft-body flap. This flap is normally made of aluminium and ceramic insulation for the shuttle. Other trial parts made by Boeing include panels, stiffeners, honeycomb structures and mouldings.

Under the contract which began in 1977, the company is developing manufacturing techniques and processes for the new material and demonstrating its structural suitability. "We're taking the material from the laboratory to the factory by developing practical fabrication methods." commented John Hoggatt, Boeing technical manager of the programme.

The new polymer which can withstand temperatures up to 600°F (315.6°C) is known as PMR-15 polyimide. Graphite in threadlike filaments is added to the polyimide in its resin state to give the material structural properties that result in a very high-strength and rigid material which is considerably lighter than aluminium.

Temperature resistance is important for materials in space shuttle applications because of the heat generated during re-entry into the Earth's atmosphere. By using a more heat resistant substructure, the weight of the ceramic insulation can be reduced.

The fabricated parts being built by Boeing also will demonstrate the quality control, manufacturing and inspection procedures developed by Boeing during the first phase of the contract. Completed parts were recently delivered to NASA for evaluation.

THE ISEE FAMILY

The U.S. satellite ISEE 3, the third element of the ISEE programme, was launched by a Thor Delta 2914 from Cape Canaveral on 12 August.

The ISEE 1, supplied by NASA, and the ISEE 2, developed and built by ESA, were launched in tandem on 22 October 1977. From a highly-eccentric orbit (perigee 280 km, apogee 138,000 km) they now supply data on magnetospheric phenomena, their fluctuations, their effects on the Earth's environment and, in particular, their velocity and directional characteristics in space and the separation of spatial from temporal variations.

From the heliocentric orbit of ISEE 3, stationed between the Sun and the Earth at a distance of 1,500,000 km from the latter, it is possible to make important interplanetary measurements and to record phenomena related to the solar wind - phenomena which, as they approach the Earth, may be responsible for most of the disturbances occurring inside and around the magnetosphere. European participation in ISEE 3 relates to the following three experiments:

- Investigation of protons in interplanetary space (Imperial College, London, U.K./Space Research Laboratory, Utrecht, Netherlands/Space Science Department of ESA).

- Study of the composition of solar particles (Max Planck Institute, Garching, W. Germany).

- Study of magnetic field-lines emanating from the Sun (Paris Observatory, Meudon, near Paris, France).

The mission as a whole was timed to make an important contribution to the International Magnetospheric Study (1976-1979) based mainly on the ESA Geos programme and whose aim is a full understanding of the near-Earth environment.

'ENTERPRISE' FINAL DYNAMICS TEST

Space Shuttle 'Enterprise' and its External Tank (ET) had to be removed from the 400 ft (122 m) tall dynamics test stand at NASA's Marshall Space Flight Center in Huntsville, Alabama, on 31 July after completion of the first phase of a year-long series of pre-flight tests in the tall structure.

After modifications were made to the test stand, 'Enterprise' was re-installed inside together with its companion ET and Solid Rocket Boosters. This was the first time an entire Space Shuttle was ever assembled.

29TH IAF CONGRESS

By L. J. Carter

PART ONE

Introduction

The main venue for the 29th IAF Congress was Hotel Libertas, a mile or so along the coast from the old walled city of Dubrovnik, a medieval town on the Adriatic coast which, in the 15th-16th centuries, possessed a fleet second only to that of Venice.

Hotel Libertas was one of the many spacious new hotel complexes built on a coastal spur to a distance of eight miles or so. Since delegates were spread over many of these hotels, the host-Society ran a (free) coach shuttle service to coincide with the various Congress events and this worked very smoothly indeed.

Hotel Libertas, itself, was completed in 1971 and was unusual because the entrance lobby by the road was actually the top of the building, the rest of the hotel being built *downwards* along the contours of a steep cliff and down to the rocky shore. The Banqueting Room, used for some of the main meetings, could easily accomodate up to 1,000 people, and there were many other large-sized rooms spread all around, thus making it easy for the many sessions to be conducted simultaneously, and still leave plenty of space over for administration, delegates to relax in, etc. In fact, even with so many people around, there seemed to be whole areas of the hotel which looked deserted.

Organisation

The host-Society for the Congress was the Yugoslav Astronautical and Rocket Society (YARS) and it has to be said at once that they did an absolutely magnificent job. There were plenty of problems of course, e.g. hotel overbookings had disconcerting effects on the individuals concerned, and, as usual, some of the projection equipment tended to live up to its high-failure rate. Some of the speakers, too, introduced problems by providing slides crammed with data but of miniscule size and totally illegible! But, set against the sheer size and magnitude of the task accomplished, such problems faded into insignificance and it seems incredible, in retrospect, that so much could be accomplished so well.

Welcome signs to IAF were hoisted within the old town of Dubrovnik. A special rocket display was mounted in the museum, with free admission to participants.

Opening Ceremony in the Banqueting Hall of Hotel Libertas.

Registration

On Registration and payment of the appropriate fee ($80 for full participants, $50 for accompanying persons and $10 for students) each participant was handed a lapel badge and a lockable document case containing booklets on the Congress programme and Abstracts of Papers, maps and brochures, a List of Participants, souvenir metal badges and stickers etc.

Stalwarts from previous Congresses set to work at once to check through the List of Participants for former acquaintances, and run through the programme to determine how best to use their time. With no less than 46 technical sessions to choose from, some listing papers and others 'with papers to be announced,' plus the business sessions, group and committee meetings, etc. all going on non-stop, selection of this sort was something of a tricky business. There were few occasions, for example, when less than six technical sessions were going on simultaneously. One had only to get tied up for a while, or be committed one afternoon, and all six became unattainable.

Having sorted out one's optimum, so to speak, the next step was to search through the Abstracts of Papers to make sure that one really was on the ball.

Congress Programme

As the number of papers listed was 350, from 24 countries, this was quite a formidable task, but the obstacle race wasn't over then by any means, because many papers listed were not presented (between 5-10%); some were read by other than the named authors, and new papers (often of great interest) had an un-nerving tendency to appear most suddenly.

Presentations at short notice by deputizing speakers sometimes had peculiar results. For example, one speaker was reading a paper at short notice on displays suitable for Shuttle pilots. It concluded with the actual layout of a display. This was the very meat of the paper. Unfortunately, it needed to be explained and the volunteer speaker was forced to admit that he hadn't seen it before. This negatived virtually the whole of the presentation.

As might be expected, American papers predominated (108 listed) with the Soviets next (58), though, in truth, there was very little in the way of new information flowing from the Soviet side in spite of their large number of papers.

Roy Gibson (BIS Fellow) elected as President of the IAF for 1978/9 on the nomination of the Society. Mr. Gibson joined ESRO in 1967 and became Director General in July 1974. He is currently Director General of the European Space Agency.

On the other hand there was a heavy flow of information outwards from the US side, so creating a very marked imbalance.

Third in number of papers were the French (46), German (28); Yugoslavia (22); Italian (17) and Japan (11). The European Space Agency booked 11, though many were read by someone other than the authors.

Most countries trailed behind, i.e. there were 18 presenting 7 or less contributions, the UK coming towards the rear and reflecting current official and industrial disinterest or economy measures.

International corner. The IAF was characterised by many freely international exchanges. Here (left to right) Wernher Buedeler, Prof. Dr. Bruening, Prof. Santini and L. J. Carter (our Executive Secretary) pause for breath over coffee. With back to camera is one of the many French participants (next to the USA, France provided the greatest number attending from any one country).

Participants

The number of participants at the Congress was given as 816, as follows:

526	Full, i.e. paying the maximum registration fee.
147	'Accompanying persons' i.e. wives.
41	Students
82	Press Representatives
20	Organising Committee
816	

No account seems to have been taken of staff, presumably because this was (mainly) State-provided.

In terms of individual countries, 181 of the total participants came from America: France provided the second largest contingent (89), no doubt reflecting the intense space interest in that country, and the USSR coming third with 71. The UK trailed behind with 17 (excluding expatriates e.g. from ESA and who were listed under a variety of other countries instead), though this is roughly comparable with earlier Congresses, certainly so since "official" participation became the order of the day, perhaps because the private individual found it hard going to shell out what was probably quite a considerable sum each time.

There were five cosmonauts at the Congress, namely Leonov, Kubasov and Klimuk from the USSR, Remek, the new Czech cosmonaut and Hermaszewski, the new Polish cosmonaut.

A report of their press conference mentioned that further Soviet programmes for international manned missions are envisaged, probably within the Intercosmos programme, and with cosmonauts from Bulgaria, Cuba, Hungary, Mongolia and Rumania.

"The Reporter"

Members of the Press attended the Congress free of charge and, from time to time, departed into their special lounge to collect their press releases, seek interviews or write their stories.

For the rest, news was provided by a four page daily Congress newspaper, printed mainly in English and distributed each morning free of charge, called *The Reporter*. The news sheet did a really good job. Few of the participants could have had any idea of what was going on outside their own particular world, so the paper did a great service by bringing together all the various Congress happenings.

Welcoming Reception

A Welcome Reception was provided on Sunday 1 October, on the evening preceding the Congress, hosted by the Yugoslav Astronautical and Rocket Society. Guests were welcomed by the President of YARS on arrival and were then free to chat, imbibe, or sample a variety of snacks for most of the evening. Those staying at the Libertas, where the function was held, probably got the best of this: for the others, a quick flit was necessary to catch the bus back to the outlying hotels.

Opening Ceremony

On Monday morning, 2nd October, delegates crowded into the beautifully-appointed ultra-modern Conference Hall in the hotel for the opening ceremony. Well over 1,000 people attended. At one end, on a raised dias, IAF and Civic dignatories sat before an enormous blue backcloth showing the IAF motif picked out in white, a representation of the Yugoslav flag with symbolic stars, all crowned by "XXIX Congress IAF," in modern style. Addresses of welcome were given, beginning with that of Professor T. Andelic (President of the Yugoslav Organising Committee) followed by those representing the Government and Municipal Authorities, the United Nations and concluded by remarks from the IAF President.

Short intervals were filled with a selection of Yugoslav folk songs played by the Dubrovnik City Orchestra.

The Congress then moved into the opening paper, on the theme of "Astronautics for Peace and Human Progress" – which had been adopted as the theme of the Congress – given by Professor L. Sedov (USSR), followed by the first of the Forums on current events with the title of "On-Going Space Activities."

"On-Going Space Activities"

The two Forums, together, were designed to provide overviews of national and international space programmes. The opening session was due to be opened by Dr. Robert Frosch, the NASA Administrator, but as he was prevented by other duties from giving his address then, it was held over until later.

Instead programme reviews were introduced first by Roy Gibson, Director General of the European Space Agency, and then by Boris Petrov, Chairman of Intercosmos Council (Moscow). Appropriately enough, the expression of UN interest which followed was given by Peter Jankowitsch, Chairman of the UN Committee on the Peaceful Uses of Outer Space. Pierre Morel, Deputy-Director-General of CNES, described the French National Programme and put across the impression of a country which knows what it is doing, though he also pointed to the need to cut down on national space activities if one was to channel resources into ESA. It was essential to maximise international cooperation to attain a programme which could be related to those of the USA and USSR. He was particularly enthusiastic about the new Earth observation camera developed for use with the SPOT satellite. The satellite, which will weigh between 1-1½ tons depending on the amount of hydrazine put into the tanks and stages in the construction of the Ariane rocket launcher, is expected to be placed into orbit next year from Kourou.

A. Matsuura, Vice President, National Space Development Agency (Tokyo) underlined the wide range and steady planning which had gone into the Japanese programme: the impression was one of a well-organised development scheme.

The talk by Mr. L. W. Morley, Director-General, Canada Center for Remote Sensing was based, mainly on the recently published booklet "Canada from Space."

Every year Canada spends millions in searching its remote North for lost aircraft and ships. Even with the use of emergency transmitters, aircraft have to fly back and forth for miles to try to pick up a signal. Now it has been shown that these signals can be picked up by satellite. This makes Seasat vital – it will be able to pick up signals from ships, aircraft and buoys all around Canada's coast, and will also introduce such services as ship routing, fisheries protection, ice monitoring, as well as ship and air rescue.

Dr. Scandone, Director of the Space Research Committee, Consiglio Nazionale delle Ricerche (Italy) said that they would fly six experiments in the first Spacelab. Up to now Italy has never had a substantial satellite programme – in spite of the San Marco launches still planned for 1979-80, with others to follow. Italy is, therefore, now preparing a five year space programme which will include a direct broadcast TV satellite and an advanced technological satellite.

The Dutch mentioned that they were preparing a successor to the Infra-red Astronomical Satellite, probably a commercial satellite.

Indonesian, Polish and German Democratic Republic speakers followed. The GDR speaker based his talk on a 10 minute film about participation in the Intercosmos programme. When asked, subsequently, about the total of GDR space expenditure he replied that it was all paid for by the Soviets and that GDR actual expenditure was no more than a few thousand dollars!

Missing from all this was a statement from the UK, hopefully a matter to be corrected next time round. If the UK has, indeed, well-defined coherent space objectives, many people in the IAF would like to hear about them.

Similarly, China, too, was absent from the table but the current re-approachment now developing might well correct this also for the future.

[To be continued

1979 SUBSCRIPTIONS

No change has taken place in the basic Subscription Rates for 1979 which are detailed below. Renewal forms were included in the Sept./Oct. issue of 'Spaceflight.'

	Sterling	*US Dollars*
Members (under 21)	£9.50	$20.00
Members (21 and over)	£10.50	$22.00
Senior Members	£11.00	$23.00
Associate Fellows	£11.50	$24.00
Fellows	£12.00	$25.00

The above fees include the receipt of *one* of the Society's publications. A further £11.50 ($24.00) should be added where members wish to receive *both* publications.

Members who remit by Bankers Orders are urged to ensure that the amount authorised are the current rates.

Remittances from Europe must indicate a UK address at which payment will be made.

Payments may be made by GIRO – either in the UK or abroad. Our account number is 53 330 4008.

International Money Orders from USA or Canada can only be cashed if expressed to be payable in sterling. (Internal money orders from those countries cannot be cashed abroad).

Fellows, Associate Fellows, Senior Members and Members who are 65 years and over on 1 January 1979 may claim a reduction of £1.00 ($2.00) from their annual subscriptions.

Remittances may be sent now to:-

The British Interplanetary Society,
12 Bessborough Gardens, London, SW1V 2JJ, England.

CHANGES IN MEMBERSHIP GRADES

Members who wish to upgrade their membership status when renewing for 1979 are reminded of the following:

(a) Transfer to Senior Member can be made by any person who has been a member for not less than five years.

(b) A new Council ruling on the qualifications needed for transfer to Associate Fellow takes into account long-standing association with the Society. The regulation specifies that a person who has been a member for more than 10 years shall be eligible for transfer to Associate Fellow.

BIS DEVELOPMENT PROGRAMME

SOCIETY MEETINGS

The work of the B.I.S. Programme Committee depends for its success on the continual inflow of new information and ideas from members on topics and events that are likely to attract good audiences and be written up for publication in *Spaceflight* or *JBIS.*

The Society's programme of meetings covers a broad range of activities which are directed to both technical and non-technical audiences:

– *Popular and educational meetings* include film shows, lectures and discussions, generally presented at evening meetings. The lectures are usually addressed by distinguished experts, and afford a unique opportunity to meet outstanding personalities in astronautics. From time to time, visits to various establishments are also included in the programme.

– *Technical and scientific meetings* are usually concerned with some specific subject-area and intended mainly for persons working in that particular field. They usually occupy one or more days where the subject is considered "in depth". Typical technical meetings, at which 20 or more papers may be presented, have been concerned with space materials, communications satellites, sounding rockets, etc.

– *The European Space Symposia* are three-day meetings sponsored since 1961, by the Society and its sister-bodies in France, Italy and Germany, and supported by EUROSPACE.

– *The International Astronautical Congress* is now supported by over forty bodies from thirty-five countries. It lasts for a week and is held at a leading city in the world each year. Additional specialist symposia are arranged in conjunction with the Congress by the International Academy of Astronautics and the International Institute of Space Law.

The B.I.S. was a founder-body of the International Astronautical Federation and was host-Society to the Congress in 1951 and 1959.

The Programme Committee already has in mind the introduction of several new ideas for later meetings, but would also welcome any further suggestions which members might wish to advance.

Offers to present lectures would also be of interest. These could range from a contribution to a technical symposium or space study series, to a general lecture on some selected topic or to a contribution to a space miscellany-type meeting.

Please do not hesitate to put any ideas forward to the Committee, by writing in the first instance to our Executive Secretary, Mr. L. J. Carter, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ. England.

CHARON - A COMPANION TO PLUTO

By Anthony T. Lawton

Introduction

The U.S. Naval Observatory announced on 7 July, 1978 the discovery of a satellite to Pluto, the 'fringe' planet of the Solar System. Dr. J. W. Christy of the Naval Observatory Flagstaff, Arizona, the discoverer, has named it "Charon" (pronounced Karon) but this awaits confirmation. In the true style of Greek mythology, the name is derived from the ferryman whose boat carried the souls of the dead across the river Styx. On the far bank of the river lay the underworld of darkness - and Pluto was the ruler of this gloomy kingdom!

Discovery of Charon

The discovery was serendipitous (i.e. a happy chance) for when the satellite was first noticed it was thought to be a flaw or a speck of dust on the plate. Using the 155 cm (61 in) mirror at Flagstaff, Christy photographed Pluto on the nights of 13th, 20th April and 12th May, 1978. All of these showed the image of Pluto as elongated, thus increasing the suspicion that a companion was present. Then Christy hunted through earlier photographs of the planet from plates taken on 13th, 15th, 16th, 17th and 19th June, 1970 and on the 29th April and 1st May 1965. *All* of these plates showed varying degrees of satellite orbital imagery, a typical example of which is shown in Fig. 1 (a).

Even then Christy was not satisfied, and on 2nd and 5th of July, 1978 he took further confirmatory photographs with the Flagstaff instrument. Meanwhile he had privately informed Dr. J. A. Graham at Cerro Tololo (Chile, South America) who took photographs on the 6th July, 1978 using the superb 400 cm reflector telescope. This instrument is rated as one of the finest in the world - and again results were positive.

Christy also informed Dr. J. Derral Mulholland of McDonald University, Texas. He likewise photographed the planet on 6th July and confirmed Christy's findings.

Supported by this evidence, Christy announced the discovery on 7th July [1], and simultaneously Graham announced the supporting findings of Cerro Tololo [2]. Details were also quoted later in [3, 4].

Characteristics of Charon

Charon has several surprises to offer, the first being its size. From the best photographs obtainable, it appears to have a diameter about ⅓ that of Pluto which means that it is about 850 km across. This is approximately ¼ the size of the Moon and gives a mass ratio of satellite to primary of approximately 30 - 1. This is a greater ratio than that of Earth and Moon (81.4 - 1) and so the Pluto-Charon system also ranks as a "dual planet". The Earth therefore loses a property thought to be unique.

The Charon-Pluto system *is* unique in that Charon may be in a synchronous orbit around its primary. It is a natural 'hadeo synchronous' orbit (Hades and Pluto are *synonymous* when applied to the *god*, Hades is *unique* when applied to the *underworld*). The hadeosynchronous orbit means that Charon stays over the same area of Pluto continuously; it would neither rise nor set. It would be quite an impressive sight, for orbiting at the calculated distance, it would subtend an angle of 2.56 degrees which is five times the size of the Moon in our own skies. It would almost be as brilliant, for basic calculations show that for the presently estimated orbital distance, and an albedo of 0.6, the apparent visual magnitude should be between -9 and -9.5. This corresponds roughly to our Moon in the first quarter.

Note added in proof:
I would like to thank Dr. Andrew Fabian for pointing out that we are not sure of the synchronous nature of Charon's orbit. The brightness fluctuations which form the basis of determining the rotation period of Pluto may actually be due to the revolution period of Charon. Further measurement may be necessary to determine Pluto's "day" with certainty. A.T.L.

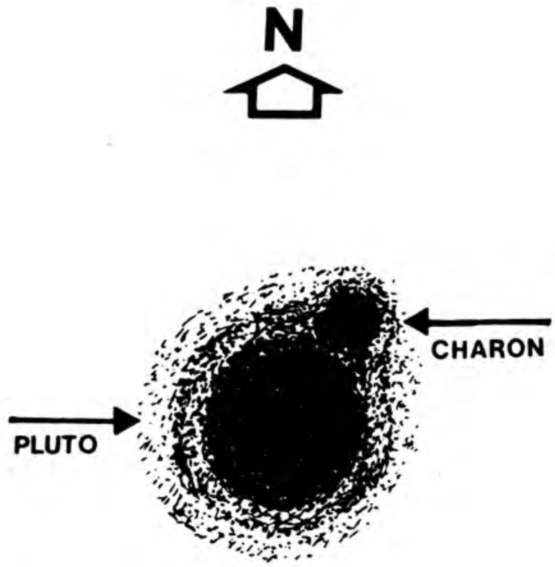


Fig. 1(a) – Sketch of a typical photograph of Pluto and Charon. The system is not fully resolved, i.e., the images are not fully separated. This applies to all photographs taken to date (Aug. 1978). Full resolution would be absolute confirmation that Charon is a satellite.

Pluto is often quoted as a "gloomy dark world" - this is simply not true! The Sun will appear as a brilliant point of light with a *mean* visual magnitude of about -19, which is about 1600 times brighter than our full Moon and quite comfortable for reading a newspaper. To an observer on the Plutonian side facing Charon, the satellite will appear to go through phases similar to our Moon but with a complete cycle of 6.39 days (the precise period is 6.3867 [5]).

The details of the orbit are shown in Fig. 1 (b) which shows the relationships between distance from primary and the spin and orbital periods of Pluto and Charon.

Origins of Charon

The discovery has of course sparked off speculation about the origin of Charon. Dr. Robert Harrington and Dr. Thomas Van Flandern also of the U.S. Naval Observatory Flagstaff have proposed a theory which involves a tenth planet with a mass of 3 to 4 times that of Earth which passed through the satellite system of Neptune. At that time it is also assumed that Pluto was a satellite of Neptune. Pluto was ejected from the Neptunian family and Charon was created by the tidal forces produced by the disruption. On the Neptune side of the catastrophe, Triton was reversed in its orbital motion to its present retrograde status and perhaps Nereid's abnormal eccentricity was also attributable to the encounter. This is a modification of the original theories produced by Lyttleton and Kuiper; and such theories are necessary to explain the orbital intersection of Pluto and Neptune, as well as the

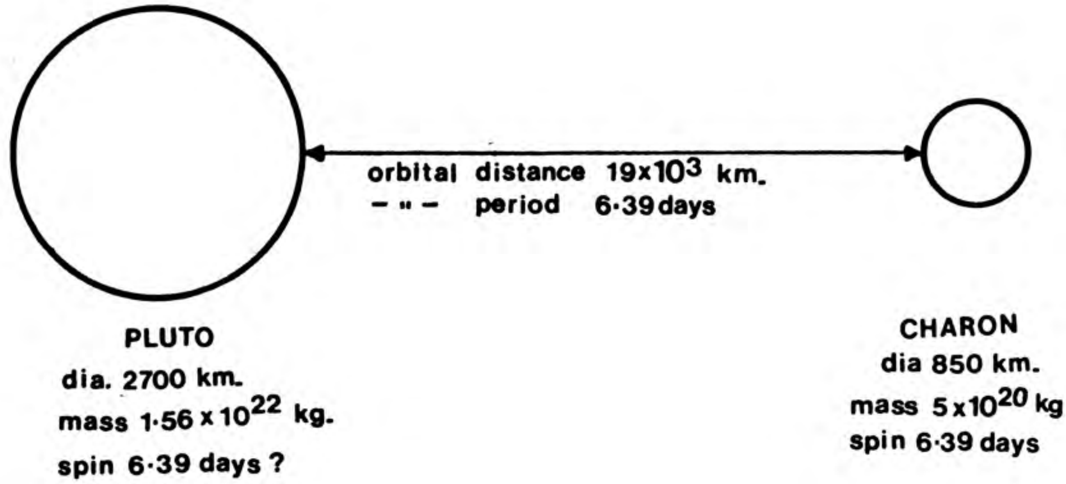


Fig. 1(b). The Orbital Elements of the Pluto-Charon system.
The revolution of Charon and Pluto could be synchronous, but this has not been verified, for the discovery of Charon may invalidate measurements of the rotation period of Pluto. Hence the query. The brightness fluctuations which were used to measure Pluto's "day" may actually have been due to Charon.

seemingly badly disciplined behaviour of their satellites!

The theory begs the question, "What happened to the tenth planet"? Harrington and Van Flandern suggest that it was flung out to 50 - 100 A.U. from the Sun, where it orbits at a distance too far away to allow it to be seen.

I would suggest that future space projects now being planned will be able to provide further evidence for or against such theories. Pluto comes to perihelion (closest approach to the Sun) in 1989, and it is now timely to begin close observation of this baffling little world. During the first half of the 1980's the NASA Space Telescope will be launched, and high resolution photography of Pluto and Neptune *should* be on the task list. If there *was* a Neptune catastrophe we might expect to see further satellite bodies, and possibly rings of debris representing the "evidence after the crime".

Gordon Taylor of the Royal Greenwich Observatory has proposed a more immediate and less exotic experiment for Pluto. In 1980 the planet should occult a 12th magnitude star, but at present the precise shadow pattern is difficult to forecast. Hopefully, we may learn more about Pluto and Charon should the occultation occur.

Revision of Plutonian Mass

The discovery of Charon has placed an upper limit on the mass of Pluto; it is 0.0026 that of Earth, and Harrington considers that a figure of 0.002 is more likely.

This increasingly supports the theory that Pluto was discovered accidentally and that the reported perturbations of Uranus and Neptune are due to inaccurate observations or that the '10th planet' still awaits discovery. This will be the subject of a future article.

"Why Was it Not Seen Before?"

I have posed this rhetorical questions because it would seem that an object of 850 km diameter and albedo 0.6 must be fairly obvious - so why no reports of it being seen or suspected earlier?

I believe that the answer lies in two areas:

(a) The nature of Pluto's orbit is such that at the time of the planet's discovery in 1930, it was so far away that a satellite at 19,000 km was beyond the resolution of all contemporary telescopes. Even the Mount Wilson 100 in (2.54 metre) mirror only showed a point of light rather than a planetary disk.

(b) Astronomers use large telescopes for photographing the most distant parts of the Universe - not comparatively nearby pint sized planets! And this is the proper use for such special facilities, for note that even in 1978 a 155 cm telescope was used on most of the work; the 400 cm mirror at Cerro Tololo was only used once. Time is precious on large telescopes!

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MISSIONS TO SALYUT 6

By Gordon R. Hooper

Continued from November issue, p. 380]

Soyuz 28
On 2 March at 15.28 (all times expressed in GMT), the Soviet Union launched Soyuz 28, callsign Zenits, carrying a two-man crew. The commander was Colonel Alexei Gubarev, who had previously flown as commander of Soyuz 17 in January 1975. His companion on Soyuz 28 was Czechoslovakian cosmonaut Captain Vladimir Remek, the first man to fly in space who was not a citizen of either the United States of American or the Soviet Union. The second man on a Soyuz flight is normally the flight-engineer, but Remek was designated a "cosmonaut-researcher."

Following a trajectory correction, Soyuz 28 was in an orbit with the parameters 309 x 269 km (192 x 167 miles) x 90 min. x 51.6°. The flight programme envisaged a docking with Salyut 6, following which the crew would conduct observations of outer space and of the Earth's surface, and perform technical, medical and biological experiments.

First Intercosmos Cosmonaut
The inclusion of a Czechoslovakian in the crew took place under the agreements dated 13 July and 14 September 1976 between the Socialist countries belonging to the Intercosmos programme. Details of these agreements have previously appeared in two articles by the present author in the Space Report section of this publication (*Spaceflight* Vol. 18, No. 11, p. 396, and *Spaceflight* Vol. 19, No. 3, p. 81). Basically, the delegations from Bulgaria, Cuba, Czechoslovakia, the German Democratic Republic, Hungary, Mongolia, Poland and Romania all agreed to fly cosmonauts onboard Soviet Soyuz spacecraft and space stations in the period 1978-83.

The launch of the Soyuz 28 spacecraft was watched by a Czechoslovak delegation headed by Josef Lenart, a member of the Presidium of the Central Committee of The Communist Party of Czechoslovakia. The delegation included Yaroslav Kozesnik, President of the Czechoslovak Academy of Sciences, and Boris Petrov, Chairman of the Intercosmos Council.

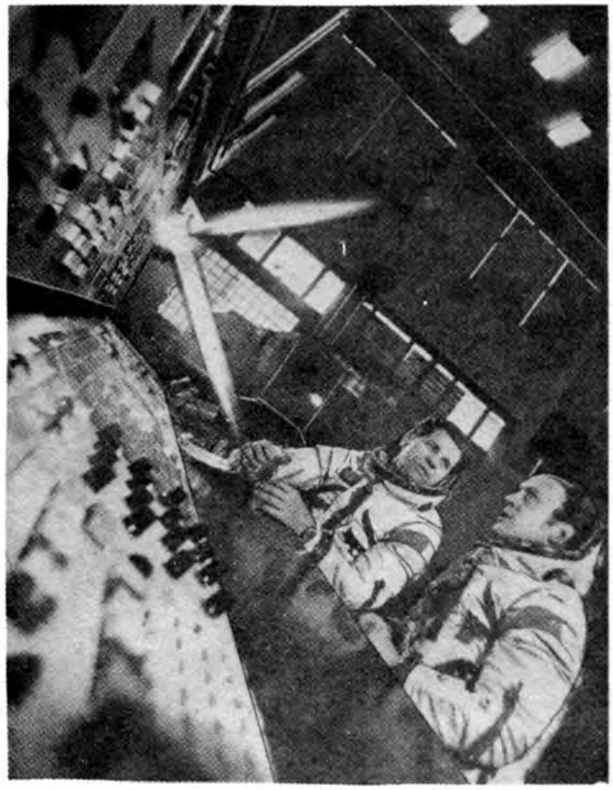
In a message to Leonid Brezhnev and Alexei Kosygin, the General Secretary of the Central Committee of the Communist Party of Czechoslovakia, and President of Czechoslovakia, Gustav Husak, together with the Czechoslovak Premier, Lubomir Strougal, said: "The first spaceflight of an international crew is a brilliant success for the Soviet space research programme, and an important contribution to the international efforts to explore outer space for peaceful purposes"

The message continued: "The flight opens up a new page in the development of cosmonautics and internationalisation of the exploration of outer space and is a big common success for our entire Socialist community."

Of the mission itself, Boris Petrov considered the flight "a tremendous event for all the Socialist community countries. During our joint work in space, we have conducted a tremendous amount of research from space orbits and this has expanded not only our knowledge about the Universe, but has also been of practical use in our countries economies."

Yaroslav Kozesnik considered it "very symbolic that the first crew from the Socialist countries should make its flight in Spring. We are indeed standing on the threshold of another Spring in our joint research programme. The scientists and cosmonauts of the Socialist countries are now setting off on the joint planned study of outer space and of our planet. Thanks to the devoted assistance of our Soviet colleagues we have set up in our country our own national school of space research and trained personnel for studying cosmonautics. March 1978 has opened the way to all the Socialist countries for further developing co-operation both on Earth and in space."

In an interview with the Czechoslovak Press Agency, Kozesnik said: "The launching of the Soviet spaceship Soyuz 28 with a Czechoslovak cosmonaut Vladimir Remek onboard is a culmination of Czechoslovakia's participation in the Intercosmos programme .... and also an expression of confidence and recognition of Czechoslovakia's science and people by the Soviet Union". He emphasized that the entering of a Czechoslovak cosmonaut into outer space was also a continuation of the Soviet Union's efforts to utilize spaceflights for peaceful purposes, it was a contribution to world peace, and to the strengthening of friendship among scientists all over the world.



Colonel Alexei Gubarev and Captain Vladimir Remek during a pre-flight training session.

Novosti Press Agency

Prelaunch Press Conference
At a prelaunch press conference held at the Tyuratam/Leninsk launch complex, Vladimir Shatalov said that six non-Soviet cosmonauts had undergone a course of spaceflight training, two each from Czechoslovakia, Poland and the German Democratic Republic. Remek emerged as the final choice after extensive final exams and tests which took place *only one month before the planned launch date.* The selection was apparently very difficult, and the examiners had to rely on "hundredths of a point" in differentiating between the candidates. Remek's back-up was Czech cosmonaut Oldrich Pelcaz. Back-up flight commander was Nikolai Rukavishnikov.

Speaking at the press conference, Lt. General Georgi Beregovoi said: "The bloody fighting against Hitlerite fascism ended with the liberation of fraternal Czechoslovakia .... and today, a Czechoslovak citizen is the first who, along with

a Soviet cosmonaut, will participate in the work whose aim is to use cosmic space and to obtain scientific research findings for peaceful purposes. In this respect our co-operation is a splendid example for nations of the whole world."

Vladimir Remek said: "Ever since the training started, I have felt immense responsibility, because I am here not only representing myself, but also my country Czechoslovakia, which has been given an opportunity to take part in the spaceflight .... Our task is to carry out several experiments which will serve the further development and promotion of knowledge on outer space and can be of use to the national economies of both countries. It is wonderful," he continued, "that we all take part in spaceflights together. The prospects of astronautics and its development call for concerted effort of all the countries concerned in preparing and carrying out space flights. Thanks to international co-operation, experts from different countries will be able to do research directly onboard the space laboratories. Our pioneer joint flight is just a first step in this direction. We are going to test in practice the compatibility of people of different nationalities during a long mission aboard the same spacecraft."

Radio Prague reported that the Presidium of the Czechoslovak Federal Assembly had approved a law establishing the honorary title of "Cosmonaut of the Czechoslovak Socialist Republic." It was one of the highest Czechoslovak distinctions, and was to be conferred to Czechoslovak and foreign citizens "in appreciation of their successful fulfilment of tasks during spaceflights." The right to award the title was conferred on the Presidium of the Czechoslovak Socialist Republic.

Docking with Salyut

By 11.00 on 3 March, Soyuz 28 had completed 13 revolutions of the Earth. The spacecraft carried out trajectory corrections and closed on the Salyut 6 station. The external cameras first picked out three beacons on the space-lab, and shortly afterwards, the station itself could be seen. The cosmonauts reported that they could clearly see the docking system at a distance of 200 m (218 yards). Docking occurred at 17.10, and was carried out "efficiently, concertedly and with complete mutual understanding between the two crews." The Soyuz 28 vehicle had docked at the aft docking unit.

Following three hours of checks on the security of the docking interface, the docking hatches were opened. Soviet TV and other Eastern Bloc countries belonging to the Intervision organisation later carried film of the docking itself, and of the cosmonauts transferring to the Salyut. Millions of viewers saw the four men embrace each other, and, in the now traditional fashion, toast each other with cherry juice drunk from tubes. Yuri Romanenko also came up with a traditional Soviet welcome to travellers when he invited Gubarev and Remek to take bread and salt with their hosts. The celebrations apparently went on for quite some time, as Alexei Yeliseyev, Flight Director, later reported that the four men did not sober down until late in the night, and only then with much persuasion from MCC.

Radio Moscow reported that the Soyuz 28 crew had brought with them mail and gifts from relatives for the main Salyut crew. They would be staying with Romanenko and Grechko for another seven days before returning to Earth. The radio station also reported that the East German and Polish cosmonaut candidates were completing their training and would fly in space in 1978. The other candidates from Bulgaria, Hungary, Romania, Cuba and Mongolia were to begin training towards the end of March. "Thus," the station said, "the integration of the scientific research of the Socialist countries is taking on a new form, offering a striking example of successful co-operation of fraternal nations for the good of all mankind."

In a congratulatory telegram to Brezhnev and Kosygin, Gustav Husak and Lubomir Strougal made the point that "the first joint flight under the Intercosmos co-operative programme is an extraordinarily significant political, social and scientific event exceeding the borders of our two countries." It was at the same time "an example of the very close and ever deepening fraternal co-operation between Czechoslovakia and the Soviet Union, and among all nations of the Socialist countries in various spheres of human activity."

The telegram, according to the "Czechoslovak News Bulletin," expressed sincere thanks for the selfless aid in the training of the Czechoslovakian cosmonaut, who was taking part in specific tasks of outer space exploration at a time when Czechoslovakia was commemorating the 30th anniversary of its working people's victory. "In the present ceremonial atmosphere," the message said, "we remember again the decisive share of the Soviet Union in the peaceful use of outer space to the benefit of all mankind. The first outer space flight with an international crew is an outstanding success of Soviet exploration of outer space, and an important contribution to the world effort in conquering outer space for peaceful purposes."

Cosmonauts Break American Space Endurance Record

At 02.36 on 4 March, Yuri Romanenko and Georgi Grechko broke the 84 days 1 hour and 16 minutes space duration record set by the Skylab 4 crew in 1974. The American astronauts, Carr, Gibson and Pogue were amongst the first to send congratulations to the new record holders. The Soviets themselves made little of the setting of the record, as did the two cosmonauts, asleep at the time!

During the day, the four cosmonauts carried out two Czechoslovak experiments – "Morava" and Chlorella." They also conducted a live TV session, with Gubarev and Remek acting as reporters. Flying over the Czech capital, Prague, Remek said that he was happy that Czechoslovakia was the first Socialist country in the world to send its cosmonaut into space, and that he had been selected for this task. He then conveyed "cordial greetings of the whole international crew to the Czechoslovak working people," according to Radio Prague.

Brezhnev and Husak sent a joint message of greetings and good wishes to the four cosmonauts, in which they said that the creation in near-Earth orbit of a scientific research complex consisting of an orbital station and two spacecraft, and the work of Soviet and international crews aboard the complex, opened up new prospects for the further exploration of outer space.

The message read in part: "You have the great honour of taking part in the opening up of a new stage in the joint research and use of outer space being carried out by the Socialist countries participating in the Intercosmos programme for peaceful purposes. We are confident that you will live up to this great honour and will contribute greatly to fulfilling the joint work programme for cosmonauts of the Socialist community on the orbital research complex." It continued: "International co-operation in space is one more proof of the fraternal relations between Socialist countries and fresh evidence of the strength of Socialist internationalism."

Replying on behalf of all four cosmonauts, Yuri Romanenko said:- "Dear Comrades Brezhnev and Husak, we thank you cordially for your greetings and best wishes. We promise to the Communist Party and State leadership of our fraternal countries and personally to you Comrades Brezhnev and Husak, that we shall apply all our strength and knowledge to defend the great honour of this international crew, which has started to carry out a joint programme of Socialist countries' research and utilization of outer space for peaceful purposes."

At a press conference held in Moscow, Alexei Yeliseyev said that the Soyuz 28 crew would return to Earth on 10 March, to be followed shortly afterwards by Romanenko and Grechko onboard Soyuz 27. Following this, the Salyut

would operate in an automatic mode until further crews were launched. Newsmen asked Vladimir Shatalov for an evaluation of the work of the Soyuz 28 crew. He replied: "I would like to note the good work of the international crew at all stages in the flight. From the take-off to the transfer into the orbital station, their reports to Earth were clear and their actions were knowledgeable and professional. During the most emotional moments of the flight, when the ship was being put into orbit and during the docking, the spacemen were calm and confident."

In a letter to *Flight International* on 4 March, Ralph F. Gibbons (Associate Fellow) suggested that the recent mysterious Cosmos 929 might have consisted of a Salyut propulsion system mated to a prototype Progress craft. He noted that after exactly one month in orbit (the announced lifetime of a Progress linked to a Salyut) Cosmos 929 carried out the first of its major orbital manoeuvres, raising the orbital period from 88.94 to 90.77 min. Also at this time, a 166 MHz signal ceased permanently. There were also other reasons for suspecting that part of the satellite was detached and de-orbited at that time.

Mr. Gibbons suggested that sometime before 17 August, fuel may have been pumped from the Progress to the Salyut propulsion system in an inflight test of the refuelling operation. Following the test, the Progress undocked and re-entered, whereas the Salyut propulsion system and associated instrumentation was boosted into a higher orbit.

The conclusion Mr. Gibbons reached was that Cosmos 929 may well have been the final test flight of the Progress craft, taking place as it did shortly before manned operations with Salyut 6 began. He also concluded that future pure-science Salyut stations might operate in a higher 450 km (280 miles) orbit, as demonstrated by Cosmos 929.

On 5 March, Gubarev and Remek carried out a joint Soviet-Czech experiment to study oxygen concentration in the human tissue in weightless conditions. They used a Czechoslovak apparatus – an "oxymeter" – for the experiment. During the day the cosmonauts carried out physical training, made a TV broadcast, and conducted a press conference.

Earth-to-Orbit Press Conference

The press conference was held at MCC, and the cosmonauts spoke to journalists from Socialist countries. Vladimir Remek talked about his impressions of the previous day's flight over Czechoslovakia. Asked what the cosmonauts missed most in space, one of them replied: "We miss most of all our friends and colleagues, our substitutes who had been training for the flight with us. We'd like them to travel into space too – it's wonderful work."

When asked what he would like to say to his colleagues – future cosmonauts from Socialist countries – Vladimir Remek said he'd "known some of my friends from Socialist countries for more than a year, and met others only a couple of days before. I would like to wish them good health in space, more strength to pass the complex training, at the launching, and happy returns to Earth."

Experiments in Space

The Chlorella experiment involved observations of the growth of chlorella seaweed, a rapid growing plant which absorbs carbon dioxide while at the same time giving off oxygen and generating water and food. The experiment was aimed at developing a closed ecological system for future Salyut stations.

In the Morava experiment, extensive materials processing work was conducted with the Splav-Ol electric furnace, which, according to *Aviation Week & Space Technology*, was located in the forward Salyut airlock.

The joint experiment was a culmination of earlier co-operation between the two countries on investigating the structure of rare metals and alloys. The conditions of weightlessness and the almost ideal vacuum which outer space provides at altitudes of from 200-300 km (124-186 miles) are extremely favourable for processes which require the ideal mixing of alloy components, or an even process of crystallization free from gravitation.

According to *Soviet News*, Czechoslovak scientists asked for an experiment to be carried out in the electric furnace on Salyut 6 in the growing of crystals with marked electro-optical properties. Two quartz ampoules of samples and a programme control unit were prepared for the experiment, the aim of which was to ascertain the possibility of obtaining materials for optical research, unique in their purity. The ampoules, prepared by the Czechoslovak Academy of Sciences, contained silver chlorides, lead chlorides, and copper and lead chlorides. The combining of glass and metallic samples was also conducted. Vladimir Remek was responsibile for placing the ampoules into the electric furnace.

On 6 March, the cosmonauts carried out another joint Soviet-Czechoslovak experiment, called "Extinctia." The purpose of the experiment was to obtain data on the micrometeoroid dust layer which exists at an altitude of 80-100 km (50-62 miles.) This was achieved by Gubarev and Remek observing the change in brightness of stars as they set behind the Earth's night horizon.

The cosmonauts also carried out Earth observations work. The Soyuz 28 crew had brought with them photographs developed from film used by Grechko and Romanenko, returned to Earth by Dzhanibekov and Makarov. The pictures were used by the crew to help determine where additional Earth resources photography was needed.

In a report on Radio Prague, Remek spoke about the catering facilities on board Salyut 6. "We are taking our meals three times a day," he said. "In the state of weightlessness the intake of food is not simple. All conserves or tubes containing food must be thoroughly fastened to a table."

Before lunch, Yuri Romanenko read out the text of a telegram of greetings sent by the Skylab 4 crew, congratulating the Salyut crew on their new space record. The Salyut cosmonauts thanked the astronauts for the message, and wished the Americans every success and expressed the hope that they would someday meet on the Earth, or even in space.

On 7 March, the cosmonauts completed smelting operations with the Splav-Ol furnace. They began transferring materials to the Soyuz 28 spacecraft in preparation for the departure of Gubarev and Remek. In the afternoon, they continued work on the Chlorella experiment.

During their joint work, the two crews carried out research into the cardio-vascular system using the air-tight "Chibis" suit, and the "Polynom-2" equipment.

On 8 March, the four cosmonauts had a day of active rest. They talked on the radio with relatives and friends, and listened to a concert specially prepared for them. The parameters of the Salyut's orbit were given as 357 x 338 km (222 x 210 miles) x 91.8 min. x 51.6°.

The four men had, during their mission, been conducting observations of the Earth's surface. One of their tasks was to assess geological formations in the Czechoslovakian mountains, which had importance for mineral prospecting. Upon a request from UNESCO, the cosmonauts also studied the thawing of snow in the Cordillera Mountains (i.e. the Andes.) Their findings were to be used in a world atlas of glaciers.

In a feature on Radio Moscow assessing world reaction to the Soyuz 28 flight, a leading Soviet paper was quoted as saying: "This flight serves as a worthy reply to the sceptics that claim that small countries cannot co-operate with the great space powers on an equal footing." The President of Hungary's Astronomical Society said: "We in Hungary were extremely pleased to hear that a spacecraft

Scene from TV film shown to the long-stay cosmonauts Vladimir Kovalyonok and Alexander Ivanchenkov aboard Salyut 6. Alexei Leonov (left) sends greetings and gives news from home. Second from left is Rimma, Ivanchenkov's wife; second from right Nina, Kovalyonok's wife and far right 12-year-old Inessa Kovalyonok. Centre, Zigmund Jähn of the German Democratic Republic.

Novosti Press Agency

with an international crew had been launched. We had looked forward to that moment ever since the beginning of our co-operation in space exploration with the Soviet Union. The joint efforts of the scientists and cosmonauts of the Socialist countries serves to advance science and strengthen the friendship between our peoples."

Joint Programme Completed

On 9 March, *Radio Moscow* reported that Gubarev and Remek had completed in full their programme of research, and would be returning to Earth the next afternoon. MCC reported that the weather in the designated landing area was sunny and warm. The cosmonauts had carried out more than 10 experiments. The employees of Radio Prague sent a message of congratulations to MCC to be relayed to the first Czech cosmonaut. The telegram read: "We congratulate you on the successful completion of your space mission and on your outstanding representation of our Socialist country. On your return to Earth we would like to invite you to come to Czechoslovakia Radio's foreign language broadcasts section to meet the people who have been informing listeners all over the world about the spaceflight of the Socialist countries' first international crew."

On or about 9 March, Yuri Romanenko and Georgi Grechko began an expanded exercise routine designed for maximum physical exertion to help the crew cope better with re-entry and re-adaptation to 1g. Some additional exercises were conducted while the two men wore their Chibis suits, made of an elastic crimped material. These suits added a negative pressure to the lower extremities, which pulled their blood from the upper parts of their bodies down into their legs. This placed more work on their cardiovascular systems, in a pattern similar to that experienced under 1g conditions. Although America's Skylab astronauts had a lower-body negative-pressure unit for experiments, this was not in the form of walk-around units like the Chibis suits. They also did not undertake extra exercises toward the end of their flights, simply because other mission requirements were more pressing.

A NASA doctor previously involved in the Skylab programme told *Aviation Week and Space Technology* that the added exercise should not prejudice medical data for the overall Salyut 6 mission. "It does not surprise me at all," he said, "that they made this change. They know enough about what to expect in terms of deterioration over time that they were able to prescribe this crash programme in order to get their guys back in as good shape as possible."

On 10 March, the Soyuz 28 crew carried out the final preparations for their return. Undocking occurred at approximately 10.25, according to calculations in private correspondence with Ralph F. Gibbons. Alexei Gubarev reported separation as the complex passed over Lake Baikal in Siberia, and this was confirmed by Romanenko and Grechko who reported that they could see Soyuz 28 slowly moving away. The braking engines were fired over the South Atlantic, and re-entry then took place.

The recovery fleet of five helicopters and three jet aircraft soon spotted the capsule's parachute and established radio contact with the cosmonauts. The capsule soft-landed 310 km (192 miles) west of Tselinograd at 11.44 and 40 seconds, touching down in a snow-covered field. Both men were said to be feeling well after their flight lasting 7 days 20 hours and 16 minutes.

The recovery helicopters flew the cosmonauts to the nearby town of Arkalyk, from where they were flown to Tyuratam/Leninsk. There they gave a short and impromptu interview to Radio Prague. "The most beautiful impression of our spaceflight," said Alexei Gubarev, "is the fact that we are satisfied with having accomplished our job on board the spacelab Salyut. The greetings sent us by Leonid Illyich Brezhnev and Gustav Husak left a great impression. Their message gave us strength and energy. Now we are infinitely happy that we have fulfilled the programme to the last detail. We are happy about the friendly meetings with the people of Kazakhstan who gave us a cordial welcome at the place of touchdown and in the town of Arkalyk. We also received a very cordial welcome at the cosmodrome." Asked how they felt, Gubarev replied: "We don't feel bad. Of course, we couldn't start right away, but in a month or two we'll be ready to start on a new flight."

Vladimir Remek said: "My impressions are so overwhelming that it is difficult to formulate them right now. We're glad that we succeeded in fulfilling the programme to the very last letter. We are glad that we have made a successful touchdown. I am exhilerated and moved by the welcome extended to us by Kazakhstan people at the place of touchdown and then in Arkalyk where we were taken by helicopter. It's difficult to express all this in words, and as to the work at the spacelab, we are glad we were able to work with such a crew, with comrades Romanenko and Grechko. I am availing myself of this opportunity to pass on their greetings to all television viewers, to all people in the Soviet Union and in Czechoslovakia."

Gustav Husak sent a congratulatory telegram to the Soyuz 28 crew on the successful completion of their mission. In it, he said that the flight would always be remembered in the history of space research as an example of "the international policy of the Soviet Union, evidence of the deepening fraternal co-operation between the Socialist countries

and firm friendship between Czechoslovakia and the Soviet Union."

Summing up the mission, Alexei Yeliseyev said that the aim of the flight had been to check the capacity of an international crew to work successfully in space, and thus, Gubarev and Remek had not been burdened with longer or more difficult tasks. Experiments with teams of cosmonauts from different countries under the Intercosmos programme were only just beginning, he emphasised. One of the possibilities still to be investigated is that of two crews making parallel experiments in space stations, he said. In his assessment of the flight, Vladimir Shatalov praised the teamwork of Gubarev and Remek and said they had co-operated well with the main Salyut crew. During the flight, they had made a number of proposals for improving the methods of observations and experiments.

Speaking of the importance of the joint flight, Alexei Leonov said: "An excellent beginning has been made to the great and promising task being accomplished by countries of the Socialist community. There will soon be flights by respresentatives of Poland and the GDR and in the years to come there will be flights by representatives of other Socialist countries."

On 11 March, the two cosmonauts remaining on board Salyut 6 underwent medical check-ups. The pulse rates of Romanenko and Grechko were 66 and 70 respectively, with blood pressures of 140/60 and 135/55. Gubarev and Remek also underwent medical checks at Tyuratam/Leninsk, and they were said to be well.

On 12 March, the Salyut 6 crew did a lot of physical exercise using their Chibis suits. Following this, they had further medical checks, and reported that they felt well. Soviet space doctors announced that the three months in space had caused Grechko's heart slightly to change position. In addition, both men's calf muscles had shrunk slightly, despite their special exercises, but there was no cause for concern, according to Dr. Anatoly Yegorov.

Record-Breaking Cosmonauts Prepare To Return

On 13 March, the cosmonauts began preparing for their return to Earth, and began slowly de-activating the Salyut space-station. On 14 March, they continued this work, and also rested for several hours, talking with relatives over the radio. They photographed the Earth's surface in the interests of the national economy, concentrating on Southern Siberia. During the afternoon, they were engaged in intensive physical training.

On 15 March, Radio Moscow announced that the two cosmonauts would be returning to Earth the next day. During the day, they continued to transfer experimental materials and scientific documents into their Soyuz 27 descent craft. They also test fired the Soyuz braking engine.

On 16 March, the cosmonauts climbed into their Soyuz spacecraft and at 08.00 undocked from the Salyut space-station which had been their home for the last 96 days. Following a successful re-entry, the descent module touched down in a snow-covered field 265 km (165 miles) west of Tselinograd at 11.19, said to be the exact moment planned by Soviet space chiefs. Their touchdown marked the setting of a new space endurance record of 96 days and 10 hours exactly, Georgi Grechko now being the world's most experienced spaceman, having spent an impressive 125 days, 23 hours and 20 minutes in space.

The touchdown was later shown on Soviet TV, and was seen by millions of viewers. An immediate on-the-spot medical check-up showed that the two men had stood up well to their long flight. They were then flown to Arkalyk, and from there on to Tyuratam/Leninsk, where they gave their first interview. "We're very glad to be back on our planet we love so much, on our Mother Earth." said Yuri Romanenko, "and we are glad to tell you that the flight programme was carried out in full, and that on the whole, we are feeling fine." The flight programme had involved more than 50 major experiments, ranging from astrophysical to medical studies.

The Central Committee of the CPSU, the Presidium of the USSR Supreme Soviet, and the Council of Ministers of the USSR sent a message of greetings to scientists, specialists and the six Salyut cosmonauts, following the successful completion of the first stage of the Salyut 6 mission.

The message read in part: "The joint flights of the cosmonauts from Socialist countries opens up a new stage in the exploration and utilization of outer space for peaceful purposes which the countries participating in the Intercosmos programme are systematically carrying out. Co-operation among scientists and cosmonauts from Socialist countries is a vivid manifestation of the fraternal relations between the countries.

The successful fulfilment of a long and complicated programme of research and experiments by the crew of the Salyut 6 – Soyuz orbital complex is a major new contribution to fulfilling the decision of the 25th CPSU Congress on the comprehensive exploration and utilization of outer space for peaceful purposes." The message "cordially congratulated the cosmonauts on the excellent fulfilment of their missions."

Congratulations were also extended to "the scientists, designers, engineers, technical experts, workers and specialists at the space launching centre and ground flight control services and sea ships, all the collectives and organisations that ensured the preparation, launchings and carrying out of the flights of the Salyut 6 station, the Soyuz 26, 27, 28 and Progress 1 spacecraft."

The message also gave the information that all six cosmonauts had been made Heroes of the Soviet Union, and that Remek, Grechko, Romanenko and Gubarev had been made Heroes of the Czechoslovak Socialist Republic.

Commenting on the flights, Shatalov said he would like to point out "the good work of all the crews which took part in this record-breaking flight. For their training, we drew upon the experience of all previous expeditions and made allowances for all the new problems that this flight offered. What I am referring to here is, first of all, its duration and, second, because the crews had to work in teams, it was necessary from a psychological viewpoint for them to be compatible." All the information obtained during the flight, he said, will be used in the training of the international crews which will take part in the continued work on the Intercosmos programme this year.

Dr. Christopher Craft, Director of JSC, was asked by *TASS* to comment on the flight, and he said: "I'm very pleased that the cosmonauts have returned safely, pleased to read in the press releases that they are in good health, and very pleased that the Russian Government sees the need for men in space, because I believe myself that there is a great deal that Man can do from space to the benefit of Earth. I think that the accomplishments of the Russian crew are outstanding. I was particularly impressed by the transportation of the fuel to the spacecraft from the supply craft. And I think that it is obvious that the USSR desires to continue to make great progress in space. And we look forward to continuing the good relationships with our colleagues and friends that we have developed in Russia." The American ASTP astronauts, Stafford, Brand and Slayton, also sent their congratulations to Romanenko and Grechko.

On 17 March, Dr. Anatoly Yegorov, head of the medical group at MCC said that the mission confirmed that "it is quite possible for human beings to live and work in space for a year or longer."

Romanenko and Grechko spent their first day back on Earth resting and undergoing medical tests. Both men were said to be feeling well, and a quick check-up confirmed their fitness. As expected, the re-adaptation to 1g caused certain

problems. Interviewed by newsmen, they said that they felt they were still spacemen rather than Earthmen. They had found their beds very hard, and all objects very heavy.

On 18 March, they spent another day resting and undergoing tests, and doctors were said to be satisfied with their progress. The cosmonauts had tried to swim out of their beds, instead of getting up in the normal way. The two men were still finding walking an effort, and a strain even to lift a cup of tea!

The two men, together with the Soyuz 28 crew, reported to the "Council of Experts" about their missions to Salyut 6. The Council gave a high appraisal to their work.

On 19 March, Romanenko and Grechko continued their medical tests and rest. Soviet news agencies gave details of their early reactions to the re-adaptation to 1g. "They are both still up there in space, not only physically, but also mentally," said Dr. R. Dyakonov. "When they wake up in the morning, they try to swim out of their beds. Their organs had become used to freedom from weight. Now every step is work – even turning a radio dial."

On 20 March, according to *Novosti*, the two cosmonauts ceased to feel the after-effects of their flight, exactly 100 days after being launched into space. To celebrate, they went for a walk together in a local park. This marked the end of the first period of re-adjustment to Earth conditions. After this, their schedule was changed, to include talks with engineers on the functioning of individual systems.

Georgi Grechko, commenting on the spacewalk, recalled that the sky had seemed more vast and more colourful than it had through the portholes of the Salyut. The Sun, he said, had felt hot despite the space-suit.

On 21 March, in an interview on Radio Moscow, Dr. Oleg Gazenko said: "Yuri Romanenko and Georgi Grechko have stood up well to the conditions of a long flight. Much of the credit is due to the training programme carried out on board the station. The men followed it to the letter, using special equipment. They did intensive physical exercises every day. Besides this, special machines enabled them to simulate running and riding a bicycle. They also used pneumatic suits creating artificial pressure which enabled them to keep their muscles both elastic and strong. So the training of the cardiovascular system, regular physical exercise and a specially balanced diet enabled them to keep in sufficiently good form right up to the end of the flight."

On 22 March, the two cosmonauts began preparing their mission report. On 24 March, while out for a stroll, they spoke to a correspondent of Radio Moscow, who asked how they were coping with the re-adaptation to Earth conditions. "Well," said Georgi Grechko, "I am still a bit shaky, and all of my body does feel heavy. Under the supervision of doctors we take special medical courses of physical exercises. In weightlessness we have a feeling of lightness of course, but now we feel heavy. This stroll that we are making is part of our training. Everything is going alright, and little by little we are re-adapting ourselves to conditions down here on Earth."

On 26 March, Radio Moscow reported that the cosmonauts were preparing for publication an album of photographs of the Earth, including sunrises and sunsets as seen from space. They also wanted to make a documentary film about the spacewalk. They considered this to have been the most difficult and challenging task of the entire mission.

On 27 March, the cosmonauts met the astro-physicists at Tyuratam/Leninsk. During their mission, they had observed stars, nebulae, and planets, including Venus and Mars, and in all carried out over 100 experiments.

On 31 March, Radio Moscow reported that Romanenko and Grechko had now fully re-adapted to Earth conditions They had regained their strength, their heart and muscular activity was normal again, and so was their blood circulation and weight. The doctors in attendance had decided to discontinue the special exercises, and to let the cosmonauts wear normal clothes again. For 12 days following their return, they had been made to wear special inflatable trousers designed to reduce the blood flow to their legs due to gravity.

On 1 April, *Soviet Weekly* reported that scientists assessing the work of Grechko and Romanenko had concluded that it is quite possible for human beings to live and work in space for a year or even longer. Their views were explained by the head of the medical team at MCC, Dr. Anatoly Yegorov. He singled out four crucial factors for that conclusion. Firstly, Grechko and Romanenko were, even at the end of their mission, displaying a highly creative interest in the research and experimental work that they were doing. Their programme included more than 50 major planned investigations. Not only did they carry them all out, but they also conducted nearly as many more on their own initiative. "The two cosmonauts showed an amazing spirit of creativity for work," said Yegorov.

The second factor was the accuracy with which the experts can now forecast the effects of weightlessness on the body, and the efficient techniques that have developed for neutralising them – the carefully controlled and substantial programme of physical exercises and effort under load, together with the wearing of the Penguin and Chibis suits. The effectiveness of these measures was confirmed by the physical fitness of the men when they landed and their speedy re-adaptation to Earth conditions.

The third, essential factor for prolonged flights was the size and comfort of Salyut 6. Because of its size, it was able to accomodate visitors from Earth, and these visits helped ease the psychological stress of the long flight on the basic crew of Yuri Romanenko and Georgi Grechko.

The fourth and final factor was compatibility. For a long spaceflight the chosen crew must obviously be able to get on well together. "Yuri Romanenko and Georgi Grechko were men of different ages, with different characters and habits," said Dr. Yegorov, "but they co-operated excellently throughout the flight. Their enthusiasm for their work, their mutual trust and respect, and, not least, their sense of humour, ensured for them the essential spirit of compatibility."

On 9 April, Radio Moscow reported that the cosmonauts had felt muscle pain and general weakness after their return to Earth. Their erythrocyte (red blood corpuscle) count was low, and they had lost weight. However, all these symptoms had now disappeared.

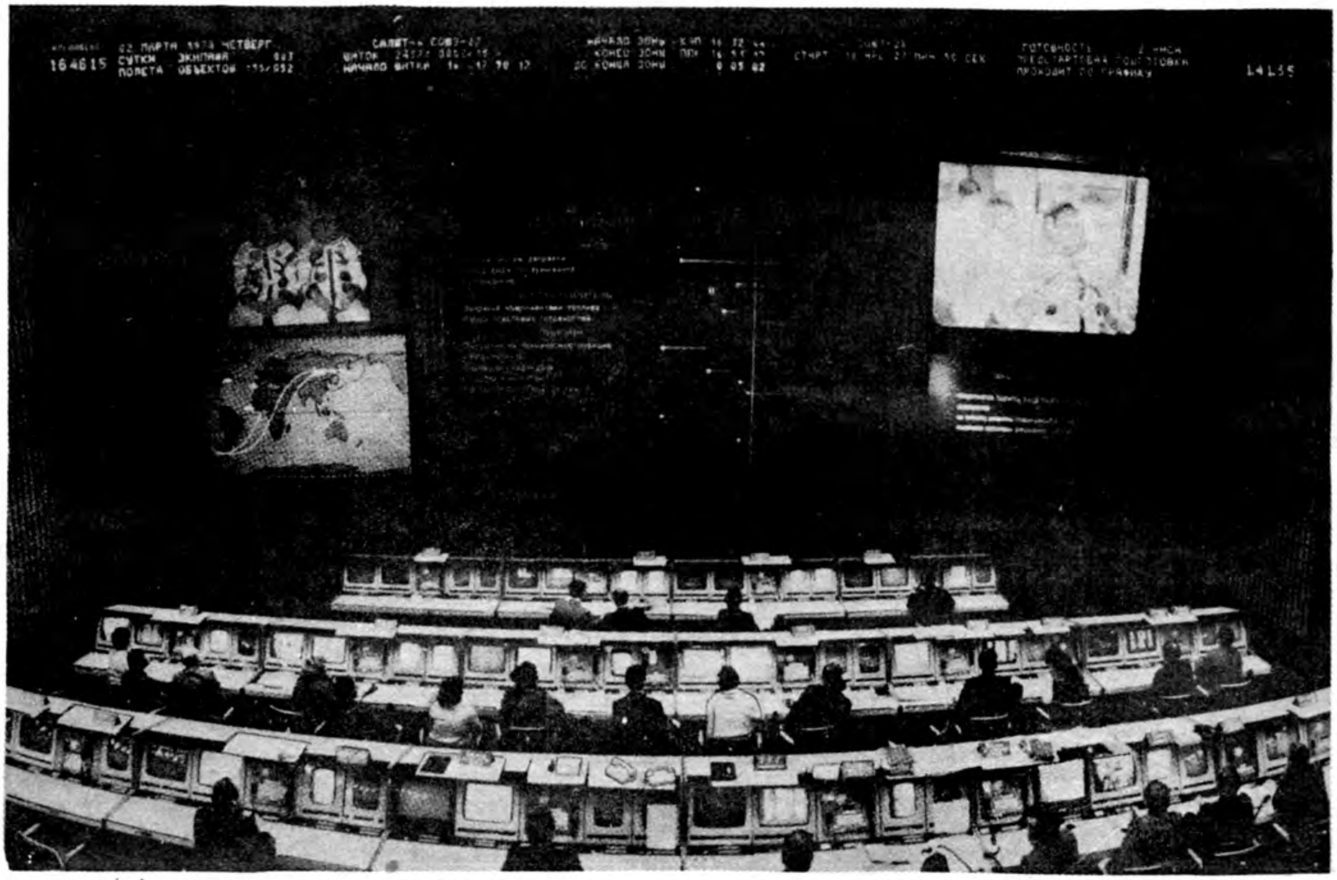
On 10 April, Romanenko, Grechko, Gubarev and Remek arrived back at Star Town, where they were warmly welcomed by relatives, friends, leading scientists, and fellow cosmonauts, including Dzhanibekov and Makarov. In keeping with tradition, the men laid wreathes at the foot of the statue of Yuri Gagarin.

More Trainee Cosmonauts

Soviet News reported that on the same day that the cosmonauts returned to Star Town, a new group of trainee cosmonauts from Bulgaria, Hungary, Cuba, Mongolia and Romania arrived to begin training.

On 11 April, a ceremony was held at the Kremlin in Moscow, where Leonid Brezhnev presented the six cosmonauts with their awards of the Order of Lenin and the Gold Star of Hero of the Soviet Union. In his speech, Brezhnev said: "the Soviet Union is honouring the achievements of those who took part in one of the outstanding stages of Man's exploration of outer space. What was done in the almost 100 days at the end of 1977 and in January to March of 1978 is a real accomplishment. It is a scientific, technological and organizational feat, but above all, it is a purely human feat.

The human race made a tangible new step in penetrating the secrets of the Universe and in subjecting them to the peoples' will and reason, thanks to an entire system of initia-



Soviet control centre at the time of the Soyuz 28 mission.

Novosti Press Agency

tives that were scupulously organised and carried out with great skill, courage and valour. This step will live on in history, just like the names of those who made it .... And we are proud that the heroes of this new space epic are our Soviet people and a citizen of fraternal Socialist Czechoslovakia. It is hard to over estimate what has been accomplished during the manned flight of the research orbital complex.

"Yuri Romanenko and Georgi Grechko broke the world record for space endurance during their 96 days in flight. Never before in the history of space exploration had there been a station in orbit with two spaceships docked to it.

"Also a first, an automatic messenger from Earth – a cargo ship with new supplies of fuel, materials, instruments, and even mail – reached an orbital station. Everything was a first and that means that everything was especially complex and involved a great deal of responsibility.

"Everything was done very well – the flight, the dockings and the fulfilment of the broad programme of important scientific and technological research.

"The cosmonauts' skill and courage and the selfless labour of those who organised the flight and ensured the precise and faultless operation of the entire sophisticated space research complex yielded fruit. A major new contribution has been made to the fulfilment of the 25th CPSU Congress decisions on developing the exploration of outer space and using it for peaceful purposes."

Brezhnev warmly congratulated the cosmonauts on their outstanding achievements and wished them new successes in their future space exploration which is exceptionally important for the country and for humanity as a whole.

"The flight of the Salyut 6 – Soyuz complex also marked the beginning of a fundamentally new stage in Man's work in outer space – this was the first flight by an international space crew. The many years of joint work on study and exploration of outer space by scientists of the USSR and other Socialist countries has now been supplemented by joint flights in outer space as well.

"We know that this is only the beginning. It will be continued. The fraternal friendship and co-operation of the Socialist community countries has gone beyond the limits of our planet to the vastness of the Universe. We take great joy in this and we are proud of it," concluded Brezhnev.

On behalf of the cosmonauts, Yuri Romanenko thanked the CPSU Central Committee, the Presidium of the Supreme Soviet, the Soviet Government and Leonid Brezhnev personally for the awards. The cosmonauts pledged themselves to devote all their energy, knowledge and experience to the cause of the further exploration and use of outer space for the sake of peace and progress, and to continue to promote the strengthening of co-operation between the countries of the Socialist community.

In his speech, Vladimir Remek said: "The participation, as such, in this international spaceflight was already a big award both for my country – the Czechoslovak Socialist Republic – and for myself as a person. I want to express my greatest thanks for the high award and for the trust placed in me by the Communist Party, by the CPSU Central Committee, by the Soviet Government and by you personally, dear Leonid Illyich.

"I assure you that I will do all I can to strengthen friendship between our peoples."

Remek then presented Brezhnev with a sculpture symbolizing the fraternal friendship of the Soviet and Czechoslovak peoples as a memento of the first international spaceflight.

Post-Mission Press Conference

Following the presentation ceremony, the cosmonauts attended a press conference. In his statement, Romanenko said:

"While preparing for this longest ever work effort in outer space, we took into account the experience of all the long flights previously made by Soviet and American cosmonauts." Grechko spoke about the research programme which had been carried out, in particular of the geophysical experiments which included observations of the Earth's surface, atmosphere and near-Earth space. These experiments served the interests of a number of fields of science and the national economy, such as geology, geography, oceanology, agriculture and forestry. The processing of the photographs taken while in orbit was being completed. Some very interesting results had been obtained concerning polar lights. In the cosmonauts' opinion, they were somehow connected with noctiluscent clouds.

Vladimir Remek thanked all those who had helped him prepare for the flight. The flight was, he said, a major event in relations between the Socialist countries, as well as a new stage in the exploration of outer space. The combining of efforts by many countries in the exploration of outer space was natural and necessary. It was noteworthy that the Socialist countries were the first to begin a new stage in space integration, he said.

At the press conference, Vladimir Shatalov announced that a Polish cosmonaut would be the next non-Soviet participant in work on board Salyut 6. He said that the flight would take place once the next two-man Soviet crew had boarded the station. Boris Petrov confirmed that a cosmonaut from the GDR would also fly to Salyut 6 in 1978.

The dates and duration of the flights were to be decided in the light of space conditions and fuller analysis of the record breaking 96 day mission. The Polish and GDR missions would involve work on materials processing, and the Soviets announced plans to fly different furnace apparatus to the Salyut for experiments to determine which hardware works best to process certain materials in zero-g.

Academician Oleg Gazenko spoke of the medical aspects of the 96 day mission. The most important result, he said, was the fact that while in orbit they retained sufficient capacity for work and successfully carried out their mission. All the experiments and observations were carried out by the crew with unflagging interest and inspiration right up to the last day of the flight.

The post-flight examination, which had been extended by the inclusion of a number of new methods – supersonic sounding of the heart, and a wide range of biological and haematological studies – had so far detected no changes differing radically from those known before. On the whole, a vast amount of scientific information had been obtained. It was of great significance both for a better understanding of Man's reactions to flight in outer space and for the further improvement of methods of medical control.

On 17 April, *Aviation Week and Space Technology* reported that the Soviets had released new data on the Salyut 6 flight. Romanenko and Grechko had spent 10-12 hours a day in the Chibis suit, which created additional work for their cardiovascular systems. The crew spent 1-3 hours a day exercising, and both men had lost 1.5-2 cm (0.59-0.79 in.) from the circumference of their legs due to inactivity of the leg muscles in zero-g, and returned to Earth with reduced heart volume. The leg and heart data were comparable to those gathered in the Skylab programme by American astronauts. Georgi Grechko had apparently experienced chest pains after returning from his 30 day Salyut 4 flight, but following his return from Salyut 6, he experienced no such problems. In fact, he found re-adaptation to 1g easier than before.

Grechko reportedly said that some of the materials processing experiments on Salyut 6 had been hampered by small gravity loads on the materials being processed. He did not elaborate, but such gravity forces would normally be associated with spacecraft-thruster-induced attitude adjustments, or reactions of the spacecraft to the cosmonauts' movements inside the vehicle. The thrusters were supposed to have been inactive during the smelting operations.

According to the same report, although Romanenko was supposed to remain inside the decompressed airlock during Grechko's spacewalk, he wanted to see the view outside, and performed an unauthorised exit of the vehicle.

On 21 April, *Novosti* reported, Salyut 6 was in a 352 x 319 km (219 x 198 miles) x 91 min. x 51.6° orbit.

On 25 April, in a feature on the selection of Poland's candidate cosmonauts, Radio Warsaw reported that a leisure programme had been devised for the cosmonaut who boards Salyut 6. Polish TV had recorded a 4 hour programme on a video cassette which the Polish cosmonaut would take with him. It included favourite pieces of music, singers and sketches.

On 27 April, Romanenko, Grechko, Gubarev and Remek arrived in Prague to be met by Gustav Husak and other Czech leaders. The four cosmonauts were presented with Gold Stars of the order of Hero of the Czechoslovak Socialist Republic the following day. Making the presentation, Gustav Husak said: "The first spaceflight with an international crew has outstanding scientific and technical importance, and also a profound political importance. It is evidence of the close co-operation and fraternity between the Soviet Union and Czechoslovakia and other Socialist countries, and of the broad co-operation which is taking place under the Intercosmos programme."

On 29 April, *Soviet Weekly* reported that the Soyuz 26 docking was almost postponed because the "Cosmonaut Yuri Gagarin" research ship stationed in the Atlantic was caught suddenly in a 40 knot gale. The "Gagarin" was responsible for controlling the docking operation, but the ship's dish antennae were only designed to operate in winds of up to 24 knots. Faced with 40 knots, two men on board the ship had to decide whether to abort the docking or to somehow try and nullify the effects of the gale.

The ship's captain, Viktor Bespalov, and the expedition leader, Vladimir Nikiforov, decided to set the antennae into the zenith position and dispense with the antennae stabilisation system. They calculated that the ship's transmitters would then give signals strong enough to allow Soyuz 26 to dock successfully – and events proved them right.

On 2 May, Radio Prague reported that Romanenko, Grechko, Gubarev and Vladimir Shatalov had visited Bratislavia in Czechoslovakia. Received by top party and government officials, they attended a rally sponsored by the Czechoslovak Academy of Sciences. The four men were then awarded Gold Medals for promoting co-operation between Czechoslovakia's scientists and scientists of the Soviet Union.

On 16 May, the main engines of Salyut 6 were fired very briefly to raise its mean altitude by 36 km (22 miles). A complex check was then made of the spacelab's systems. MCC were said to be in direct contact with the station six times a day.

On 7 June, Radio Moscow reported that the life support systems of Salyut 6, including heaters and ventilators were "to be switched on soon, to prepare the space laboratory to receive new crews." The first of these new crews was launched only a week later, on 15 June 1978, on board Soyuz 29.

Acknowledgements
The author wishes to acknowledge the following references: Novosti Press Agency, Czechoslovak Press Agency, *Soviet News, Soviet Weekly*, Moscow News, Radio Moscow, Radio Prague, Radio Warsaw, *Flight International* and *Aviation Week and Space Technology.* Special thanks are due to Ralph F. Gibbons and Phillip S. Clark for their valuable assistance in compiling this article.

[To be continued

SATELLITE DIGEST - 121

Continued from November issue, p. 395]

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information sources include the Royal Aircraft Establishment at Farnborough, NASA, Novosti and both the popular and specialist press. For a more detailed summary, see Satellite Digest – 111, January 1978.

Name, designation	Launch date lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
GEOS 2 1978-71A	1978 Jul 14.45 indefinite	Cylinder + booms 573 (fuelled)	1.10 long 1.62 dia	213 35378 35592	35536 35615 35640	25.85 0.80 0.77	626.60 1421.2 1427.3	ETR Delta ESA/NASA (1)
Molniya-1 AS 1978-72A	1978 Jul 14.63 12 years?	Cylinder-cone + 6 panels + 2 antennae 1000?	3.4 long 1.6 dia?	607 606	40666 39769	62.83 62.83	736.44 718.15	Plesetsk A-2-e USSR/USSR (2)
Raduga 4 1978-73A	1978 Jul 18.92 indefinite	Cylinder + 2 paddles + 2 antennae? 2000?	5 long? 2 dia?	36473 35716	36731 35859	0.50 0.44	1477.8 1436.1	Tyuratam-Baikonur D-1-E USSR/USSR (3)
Cosmos 1027 1978-74A	1978 Jul 27.20 1200 years	Cylinder 700?	1.3 long? 1.9 dia?	966	1004	82.94	104.82	Plesetsk C-1 USSR/USSR (4)
1978-75A	1978 Aug 5.2? indefinite							ETR Titan 3b/Agena D DoD/USAF
Cosmos 1028 1978-76A	1978 Aug 5.62 29.5 days (R) 1978 Aug 24	Cylinder + sphere + cylinder-cone 6000?	6 long? 2.2 dia?	171 167	248 335	67.13 67.14	88.70 89.54	Plesetsk A-2 USSR/USSR (5)
Progress 3 1978-77A	1978 Aug 7.94	Sphere + cone-cylinder + antennae 7000?	8.0 long 2.3 dia	190 241 327	232 249 355	51.64 51.64 51.62	88.65 89.33 91.29	Tyuratam-Baikonur A-2 USSR/USSR (6)
Pioneer Venus 2 1978-78A	1978 Aug 8.31 4 months	Cylinder + conical projections 904	2.9 long 2.5 dia		heliocentric orbit			ETR Atlas Centaur NASA/NASA (7)
ISEE 3 1978-79A	1978 Aug 12.63 indefinite				see supplementary note			ETR Delta NASA/NASA (8)

Supplementary notes:

(1) Replacement satellite for GEOS 1 (1977-29A) which was placed in a 12 hour elliptical orbit rather than a geosynchronous circular one during 1977 April. The modified orbit resulted from a fault in the launch vehicle. The new satellite will carry out the magnetospheric research programme originally envisaged for GEOS 1, its design life is two years. The satellite will be stationed between 9 and 35 deg East, depending on operational requirements. Orbital data are at 1978 Jul 14.7, 1978 Jul 18.0 and 1978 Jul 23.5.

(2) Orbital data are at 1978 Jul 15.7 and 1978 Jul 24.8.

(3) Communications satellite in geostationary orbit, carrying telephone, telegraph and TV communications. The satellite is also known as Statsionar-2 and is stationed near the Indian Ocean. Orbital data are at 1978 Jul 19.2 and 1978 Aug 10.7.

(4) Cosmos 1027 may be a navigation satellite.

(5) Long life recoverable reconnaissance satellite which did manoeuvre several times; orbital data are at 1978 Aug 5.9 and 1978 Aug 7.8.

(6) Third resupply vessel to visit Salyut 6, still manned by the Soyuz 29 crew. Unlike the previous two Progress craft, no fuel supplies were carried and the main purpose of the flight was to stock up the orbiting laboratory with food. Docking with Salyut took place at 1978 Aug 10.13, Progress 3 used the docking port on Salyut's instrument unit. Undocking took place at 1978 Aug 21.

(7) Second spacecraft of a pair in flight to Venus. Pioneer Venus 1 (1978-51A) was launched 1978 May 20. Pioneer Venus 2 carries three small and one large atmospheric probes. The flight bus is similar to that of Pioneer Venus 1 which will be placed in orbit around the planet. The entry probes are spheres, protected by conical aeroshells, the largest weighs 316 kg and the smaller ones 90 kg each. The large probe is designed to enter the atmosphere near the equator on the day side of Venus and will take nearly one hour to reach the surface, taking measurements of atmospheric composition and conditions. The small probes, two of which are targeted for the night side of the planet, will measure atmospheric conditions. Unlike the large probe, the smaller ones are not equipped with parachutes but, owing to the entry angle, will take about the same time to descend through the atmosphere. Venus encounter is scheduled to occur at 1978 Dec 9, the entry probes will separate 20 days before this and the remaining part of the spacecraft will act as an upper atmosphere sounder before burning up.

(8) Third of three spacecraft making measurements of the interaction between the solar wind and the Earth. ISEE 1 and ISEE 2 (1977-102A and 1977-102B) were launched 1977 Oct 22. ISEE 3 will be injected into orbit around the Earth-Sun Lagrange Point. The choice of an "orbit" rather than placing the satellite at the Lagrange point means that interference with communications by the Sun can be kept to a minimum; from the Earth, ISEE 3 will appear to revolve around the Sun with a period of about six months. Arrival in the "orbit" will be about 1978 Nov 28 and the craft will be used in conjunction with the other two vehicles.

Amendments and decays:

The three payloads launched along with 1977-112A are designated 1977-112D, E and F; their names are SSU 4, 5 and 6 respectively. Their shape is a box, size 0.9 x 0.3 x 2.4 m.

1978-59A, orbital data are at 1978 Jun 12.5 and 1978 Jun 22.6.

1978-62A, orbital data are at 1978 Jun 17.1 and 1978 Jul 15.0.

1978-66A, orbital data are at 1978 Jun 30.2 and 1978 Jul 18.2.

BOOK REVIEWS

Space Research, Vol. XVII
Editor, M.J. Rycroft, Pergamon Press, 1977, pp. 860, US$125.00

The annual meetings of *Cospar* are intended to bring together those scientists from around the world whose research is conducted using the data acquired by satellite, sounding-rocket or (as of 1975) balloon-borne instrumentation. Such terms of reference may not have seemed overly wide at *Cospar's* inception. However, as regular readers of this journal will be fully aware, the uses of satellite and sounding-rocket technology has expanded enormously over the past twenty years and has now spread into a very wide diversity of sophisticated applications. This fact is very well illustrated by the present volume, which contains 129 selected papers in the physical sciences presented at the 19th *Cospar* meeting held in Philadelphia, U.S.A. in June, 1976.

As a result of the wide terms of reference, the range of subject material treated is correspondingly wide, from land usage studies and geodesy, through *in situ* and remote measurements of the Earth's atmosphere and ionosphere (these subjects comprising roughly half the book), to Solar System physics and high energy astrophysics. One important subject not treated, despite the title of the book, is the physical properties of "space" itself *viz* the electromagnetic field and plasma environment constituting the Earth's magnetosphere and the solar wind (the reason being that a separate meeting was held in the U.S.A. on these subjects under *Cospar* co-sponsorship that summer, the proceedings of which are published elsewhere)..

Generally, the contributions to the book consist of short summaries of individual specialized experimental research programs at various stages of development, from those which had reached some maturity, as exampled by the reviews on the Pioneer results from Jupiter, to those still at a very initial and undigested stage. These latter were no doubt topical at the time, but, by now, many of them must have been overtaken by more detailed publications in the regular journals, due to the rather lengthy period required to produce and publish a book of this kind. Because of the nature of the papers, the wide diversity of subject material and the general lack of relevant review articles, the book as a whole lacks cohesion, despite the very large number of papers it contains and the careful editorial attention to grouping by subject area and to paper sequencing. If this book is also a fair reflection of the meeting itself, then the above comments would seem to imply that the time is rapidly approaching for a reappraisal of *Cospar's* activities and terms of reference. It is hard to imagine, for example, the relevance of coastal morphology kinematics to a scientist working on cometary micrometeoroid swarms (just to open two pages at random), despite the fact that both can be observed from Earth orbit. It is rather like insisting that hi-fi enthusiasts and computer engineers should hold joint conferences, on the basis that both of their respective pieces of equipment use transistors.

However, one important aspect of Cospar meetings which should not be overlooked is the fact that they attract considerable support from the U.S.S.R. and other Eastern bloc countries, and so provide a unique forum for mutual exchange of ideas and scientific results. Indeed, one quarter of the papers in this volume originate from this source, often presenting material which would otherwise be rather inaccessible in the West. Of particular interest are papers which briefly describe upper atmospheric research undertaken on Cosmos and Intercosmos satellites, X-ray and solar UV measurements on Salyut 4, and analyses of Venera 9 and 10 data from the surface of Venus.

In summary, it appears fair to conclude that this book will be of little interest to the general reader, and also (with possibly a few exceptions) only of limited use to the research scientist, due both to the highly summarized nature of most of the contributions and to the length of time required for their publication. However, the book has been very nicely produced and will present a very pleasing aspect to future historians seeking a 'snapshot' of current "space" research progress as of summer 1976. The only other function that this book will adequately perform will be to relieve scientific libraries of a fair slice of their book acquisition funds, and 4.35 cm. of their empty shelf space.

DR. S.W.H. COWLEY

Infrared and Submillimeter Astronomy
Ed. G. G. Fazio, D. Reidel Publishing Company, 1977, pp. 223, $22.00

Although this volume constitutes the proceedings of the symposium held in Philadelphia in June 1976, we are informed in the preface that "due to the limitations on the number of printed pages, only the invited lectures are presented as complete papers" with contributed papers appearing only in abstract. Even more disappointing – some invited lectures were not available for inclusion in the text and again "only an abstract is quoted." So, this leaves a mere 15 out of a possible 38 papers appearing as anything more than particularly unuseful abstracts. This is typified by Michel, Nishimura and Olthof's 6 line abstract of their paper *On the Detectability of Molecular Hydrogen with IRAS* which terminates with the eminently redundant statement 'A discussion will be given on the astrophysical importance of this measurement as well as an outline of the technical feasibility'! Not inspiring reading.

The volume is divided into six broad sections, the first being on general infrared astronomy and is introduced with an 'overview' on IR space astronomy by F. J. Low, (actually only a very brief outline). Part II relates to work on galactic sources with 2 out of 3 complete papers dealing with HII regions – IR emission and radio observation – and the third with the interpretation of IR emission from molecular clouds. Part III, on the Solar System, has just two full papers; one on IR observations of the Sun and the other on observations of the planets and other bodies such as comets. This latter paper suffers from a barely legible typescript: all papers in this volume – as is apparently now the norm in this series of texts – are merely photographically reproduced typed manuscripts.

Part IV concentrates on extragalactic sources and submillimeter radiation and has two papers – IR observations of extragalactic sources (Kleinmann) and the spectra and isotrophy of the sub-millimeter background radiation (Muehler). Sections V and VI both deal with observational techniques, the former with basically balloon/aircraft borne instruments and the latter with instrumentation designed for use on board spacecraft.

I do not think this, the 63rd volume in the *Astrophysics and Space Science Library*, can be said to maintain the high standards now expected of this well known series nor justify the high cost associated with these texts. Additionally, only 15 out of 38 papers hardly represent the proceedings of a three-day conference.

S. G. SYKES

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: Tel: 01-821 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor 12, Bessborough Gardens, London, SW1V 2JJ.

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Lecture
Title **A REVIEW OF BRITISH SPACE PROSPECTS**
by P. J. Conchie

To be held in the Lecture Theatre, Royal Society of Arts, John Adam Street, London, W.C.2. on **1 December 1978,** 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

General Meeting
Title **SPACE MISCELLANY – 1**

To be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1. on **12 December 1978,** 6.30-8.30 p.m.

Another opportunity for members to talk about models, or souvenirs and other items connected with space projects.

(1) M. Irvine will talk on "Space Models."

(2) L. J. Carter will talk on "Ideas for Space Collections."

Members interested in presenting short contributions to later meetings of this nature are invited to send details to the Executive Secretary.

Admission tickets are not required. Members may introduce guests.

Visit

A second opportunity to tour the Astronomy and Space Galleries of the Science Museum, Exhibition Road, London, S.W.7., for those unable to participate first time around, will be given on **17 January 1979** at 6.30 p.m.

As before, the group will be accompanied by Dr. John Becklake.

Admission (restricted to members only) will be by ticket only, available from the Executive Secretary enclosing a **reply-paid envleope.**

Short Papers Evening
Title **EXOTIC SEMI-CONDUCTOR MATERIALS**
by A. T. Lawton
Title **INTERSTELLAR COLONISATION**
by Dr. L. J. Cox.

To be held in the Kent Room of Caxton Hall, Caxton Street, London, S.W.1. on **1 February 1979,** 6.30-9.30 p.m.

Admission tickets are not required. Members may introduce guests.

Visit

Arrangements are being made for a small party of members to visit the Rocket Propulsion Establishment at Westcott, Nr. Aylesbury, Bucks. on **14 February 1979** *(all day).*

The excursion will be by train to and from Aylesbury (departure Marylebone Station).

Registration is necessary. Members interested in participating *must* apply to the Executive Secretary, enclosing a **reply-paid envelope,** no later than 28th January 1979.

General Meeting
Title **SPACE MISCELLANY – 2**

To be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1. on **8 March 1979,** 6.30-8.30 p.m.

3rd BIS CONFERENCE ON INTERSTELLAR STUDIES

To be held in the Chemistry Lecture Theatre, University College London, Gordon Street, London, W.C.1., on Wednesday and Thursday, **11-12 September 1979**. (Note change in dates).

The scope of the Conference is intended to cover all aspects of Interstellar Studies, including such topics as:

- Propulsion concepts
- Interstellar probes
- Extra-solar planetary systems
- Laser and radio communication
- Evolution of life
- Rise of intelligence and civilisation

It is planned to allow ample opportunity for discussion to take place among the participants, both informally and in final discussion sessions.

Papers presented at the Conference will be published in the Interstellar Studies issues of *JBIS*, following usual reviewing procedures.

Applications for registration forms and notification of the intention to submit a paper for the Conference, should be made to: The Executive Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ, England.

IMAGE PROCESSING TECHNIQUES APPLIED TO ASTRONOMY AND SPACE RESEARCH

Date : **15-16 November 1979**

Venue : Science Research Council's Appleton Laboratory, Slough, Bucks. U.K.

Topics:
a) Astronomical Image Processing
b) Planetary Image Processing
c) Remote Sensing
d) Interactive Processing and System Design
e) Applications of Array Processors
f) Image Restoration

Offers of Papers to be presented at this Conference should be sent to the Executive Secretary, The British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ, England.

Registration forms and programmes will be available later, on request.

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